EXHIBIT DX16

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

CONTINUING EDUCATION

Forced-Air Warming Devices and the Risk of Surgical Site Infections

MELISSA D. KELLAM, DNAP, CRNA; **LORAINE S. DIECKMANN,** PhD; **PAUL N. AUSTIN,** PhD, CRNA

3.0 CE

www.aorn.org/CE

Continuing Education Contact Hours

CE indicates that continuing education (CE) contact hours are available for this activity. Earn the CE contact hours by reading this article, reviewing the purpose/goal and objectives, and completing the online Examination and Learner Evaluation at *http://www.aorn.org/CE*. A score of 70% correct on the examination is required for credit. Participants receive feedback on incorrect answers. Each applicant who successfully completes this program can immediately print a certificate of completion.

Event: #13529
Session: #0001
Fee: Members $18, Nonmembers $36

The CE contact hours for this article expire October 31, 2016. Pricing is subject to change.

Purpose/Goal

To provide knowledge specific to the use of forced-air warming systems and surgical site infections.

Objectives

1. Describe inadvertent perioperative hypothermia.
2. Discuss the use of forced-air warming to maintain normothermia perioperatively.
3. Describe the methodologies used in the studies appraised in this article.
4. Describe the authors' conclusions about the use of forced-air warming systems.

Accreditation

AORN is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.

Approvals

This program meets criteria for CNOR and CRNFA recertification, as well as other CE requirements.

AORN is provider-approved by the California Board of Registered Nursing, Provider Number CEP 13019. Check with your state board of nursing for acceptance of this activity for relicensure.

Conflict of Interest Disclosures

Melissa D. Kellam, DNAP, CRNA; Loraine S. Dieckmann, PhD; and Paul N. Austin, PhD, CRNA, have no declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.

The behavioral objectives for this program were created by Helen Starbuck Pashley, MA, BSN, CNOR, clinical editor, with consultation from Rebecca Holm, MSN, RN, CNOR, clinical editor, and Susan Bakewell, MS, RN-BC, director, Perioperative Education. Ms Starbuck Pashley, Ms Holm, and Ms Bakewell have no declared affiliations that could be perceived as posing potential conflicts of interest in the publication of this article.

Sponsorship or Commercial Support

No sponsorship or commercial support was received for this article.

Disclaimer

AORN recognizes these activities as CE for RNs. This recognition does not imply that AORN or the American Nurses Credentialing Center approves or endorses products mentioned in the activity.

http://dx.doi.org/10.1016/j.aorn.2013.08.001

Forced-Air Warming Devices and the Risk of Surgical Site Infections

MELISSA D. KELLAM, DNAP, CRNA; **LORAINE S. DIECKMANN,** PhD;
PAUL N. AUSTIN, PhD, CRNA

3.0 CE

www.aorn.org/CE

ABSTRACT

The potential that forced-air warming systems may increase the risk of surgical site infections (SSIs) by acting as a vector or causing unwanted airflow disturbances is a concern to health care providers. To investigate this potential, we examined the literature to determine whether forced-air warming devices increase the risk of SSIs in patients undergoing general, vascular, or orthopedic surgical procedures. We examined 192 evidence sources, 15 of which met our inclusion criteria. Most sources we found indirectly addressed the issue of forced-air warming and only three studies followed patients who were warmed intraoperatively with forced-air warming devices to determine whether there was an increased incidence of SSIs. All of the sources we examined contained methodological concerns, and the evidence did not conclusively suggest that the use of forced-air warming systems increases the risk of SSIs. Given the efficacy of these devices in preventing inadvertent perioperative hypothermia, practitioners should continue to use and clean forced-air warming systems according to the manufacturer's instructions until well-conducted, large-scale trials can further examine the issue. *AORN J* 98 (October 2013) 354-366. © AORN, Inc, 2013. http://dx.doi.org/10.1016/j.aorn.2013.08.001

Key words: *intraoperative hypothermia, normothermia, forced-air warming, surgical site infection.*

Patients often report feeling cold before the induction of general anesthesia or when sedated for surgical procedures. Besides being uncomfortable, inadvertent perioperative hypothermia can be difficult to treat and have undesirable consequences for the patient, including platelet dysfunction and other coagulation defects, delayed postanesthetic recovery, prolonged hospitalization, and surgical site infections (SSIs).[1] Inadvertent perioperative hypothermia, defined as a core body temperature of $\leq$ 36.0° C (96.8° F), is the most common thermal disturbance seen in surgical patients.[1] Reasons for heat loss during operative and invasive procedures include the patient's exposure to the surgical environment and the effects of anesthetic agents and medications that interfere with the body's normal ability to regulate temperature.[1] A major physiological reason for anesthesia-related hypothermia is a redistribution of heat from the core to the periphery of the body because of vasodilation effects caused by volatile anesthetic agents.[1] There is also a similar effect seen with major regional anesthesia (eg, spinal, epidural).[1]

Health care providers often use forced-air warming systems to provide surface warming in the

http://dx.doi.org/10.1016/j.aorn.2013.08.001

OR because these devices are helpful in maintaining normothermia and preventing perioperative hypothermia.[2] However, providers also are concerned that these devices may increase the risk of SSIs by acting as a vector or causing unwanted airflow disturbances over the surgical site. Because of the perceived infection risk, some surgeons request these devices not be turned on until the patient is prepped and draped or that they not be used at all.[2] To investigate this risk, we used the following PICO (ie, population, intervention[s], comparison, outcome) question[3] to guide our search for evidence: Do forced-air warming devices increase the risk of SSIs in patients undergoing general, vascular, or orthopedic surgical procedures?

SEARCH STRATEGY

To answer our question, we examined the literature to determine whether forced-air warming devices increase the risk of SSIs in patients undergoing general, vascular, or orthopedic surgical procedures. We included evidence from high-level sources, including systematic reviews with or without meta-analysis, clinical practice guidelines, and human clinical studies. We also included lower-level studies, which included laboratory and simulation studies, because we suspected that there would be a lack of higher-level evidence to answer our question. We revised our search in an ongoing fashion to refine the search results.

We gathered our evidence by searching PubMed®, Academic Search™ Complete, and the Cochrane Collaboration databases for the period from 1990 to 2012. We used the following search terms alone and in combination: *convection warmer, convection warming, forced air warmer, forced air warming, infection, contamination*, and *complications*.

Our inclusion criteria included full-text articles in English that addressed the PICO question and were published in peer-reviewed journals or on specialty or government web sites. The population of interest included patients of all ages undergoing general, vascular, or orthopedic procedures. We appraised the evidence based on whether it helped answer the PICO question and for methodological quality using the method described by Stetler et al.[4] Two authors (MDK and PNA) evaluated each evidence source, and consensus was reached when there was disagreement. We further scrutinized the reference lists of appraised evidence, including using the "related citations" function in PubMed, to locate further applicable evidence that met our inclusion criteria.

CRITICAL APPRAISAL OF THE LITERATURE

Our search yielded a total of 192 possible sources. Fifteen sources[5-19] remained after we eliminated those that were duplicates or did not meet our inclusion criteria. We did not find any systematic reviews. The investigations we reviewed used four general methods to determine the likelihood of the forced-air warmer causing an SSI, with some studies using more than one method. The direct method was to follow patients who were warmed intraoperatively with a forced-air warmer to determine whether it led to an increased incidence of SSI,[12,14,15] and the three indirect methods were to

- examine the intake, inside, and output hoses of forced-air warming units or the air emitted directly from the forced-air warming unit for bacteria or particles that might harbor bacteria[5-8,10,12];
- evaluate bacterial counts near or on patients, volunteers, or manikins in an OR[12,15,17-19]; and
- examine unwanted airflow disturbances in the OR caused by the forced-air warming device.[9,11,13,14,16,17]

It is important to note that only one of these methods, which was used in three investigations, directly examined the likelihood of an increased incidence of SSIs caused by the intraoperative use of forced-air warmers.[12,14,15] The remaining three methods used by the other investigators indirectly examined the likelihood of forced-air warmers to cause SSIs.

Methodological Concerns

There were numerous methodological concerns with all of the investigations that we reviewed.[5-19] For example, none of the researchers described how they determined the sample size of forced-air warmers or the number of study participants. In addition, none indicated whether the forced-air warmers had been maintained per the manufacturer's instructions. They also did not perform any blinding or random allocation of participants to study groups. An important concern is that five[5,6,9,11,14] of the investigations included an author who was supported or had been supported by a company that manufactures a conductive fiber blanket that was in direct competition with makers of forced-air warming systems. Another study was supported by a forced-air warmer manufacturer.[16] We felt these represented sources of potential bias.

Direct Methods

Three investigations[12,14,15] followed patients who were warmed intraoperatively for SSIs (Table 1). All of these studies were observational studies and were part of other investigations examining bacterial counts near or on patients or manikins. One of the

TABLE 1. Summary of Evidence: Observing Subjects Who Were Warmed Intraoperatively Using a Forced-Air Warmer for Infection

Evidence source[a]	Subjects, procedure, and intervention	Findings and comments[b]
Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger® patient warming system in prolonged vascular surgery: an infection risk? *Crit Care*. 2003;7(3):R13-R16.	■ 16 subjects ■ Aortic surgery with graft ■ Forced-air warming system[c] with upper body cover (mean 234 minutes)	■ No postoperative surgical site infections at six months
McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. *J Bone Joint Surg Br*. 2011;93(11):1537-1544.	■ 1,437 subjects ■ Hip or knee replacement ■ Forced-air warming system[c] (n = 1,066 subjects) or conductive fiber blanket[d] (n = 371 subjects)	■ High risk of developing deep infections for subjects warmed with forced-air warming system (odds ratio, 3.8; $P = .024$) ■ No effect of factors such as age or diabetes ■ No records on blood transfusions, incontinency, or overall physical status ■ No control of potentially confounding factors ■ Unknown what effect history played on the results because data were collected during a two-year study period
Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect*. 2009;73(1):58-63.	■ 30 subjects ■ Hip replacement ■ Forced-air warming system[c] (n = 20 subjects) or no forced-air warmer (n = 10 subjects)	■ No postoperative surgical site infections ■ Unknown follow-up period ■ Unknown location of forced-air warmer cover

[a] *All observational studies, Level IV C evidence*
[b] *No mention of randomization, patient selection, sample size calculation, or blinding*
[c] *Bair Hugger®*
[d] *Hot Dog Total Access Warming™*
Bair Hugger is a registered trademark of Arizant Healthcare, Eden Prairie, MN. Hot Dog Total Access Warming is a trademark of Augustine Temperature Management, Eden Prairie, MN.

investigations also looked at the effect of forced-air warmers on unwanted airflow in the OR.[14]

Huang et al[12] included 16 vascular surgery patients but had no control group.[12] Moretti et al[15] examined a total of 30 female patients who underwent hip replacement surgery: 20 who received forced-air warming and 10 who did not. Neither of these studies included a comparison of groups for equivalence. The third direct investigation included 1,437 patients undergoing hip or knee replacement.[14] A forced-air warmer was used with 1,066 patients from July 2008 to March 2010 and a conductive fiber blanket was used with 371 patients from March to June 2010. The authors acknowledged that the presence of potential confounders, such as antibiotic use and thromboprophylaxis, had changed between 2008 and 2010 and could have affected the subjects' risk of SSI.[14] The groups were similar in some respects, including the type of surgery and the presence of diabetes; however, the groups were not compared in terms of other potentially confounding variables, including obesity, incontinence, and fitness for surgery.

McGovern et al[14] described the OR used as being a laminar flow room with ultra-clean air; however, the other studies[12,15] did not describe the type of OR air handling. Because the rooms were functioning ORs, we assumed the air handling met regulative standards. In addition, in one study, the method of following the subjects for SSI was not detailed.[14]

Indirect Methods

The first method that researchers used to indirectly examine whether forced-air warmers are likely to cause SSIs was to look at the incidence of forced-air warmers harboring organisms (Table 2). Six evidence sources[5-8,10,12] examined various locations in or on the forced-air warming device or the air emitted directly from the unit's output hose for bacteria or particles that might harbor bacteria. Methods used to determine this ranged from researchers simply swabbing the interior and exterior of one forced-air warmer, including the inside of the output hose, and culturing the samples in growth media[8] to examining the filtration efficiencies of 25 forced-air warmers from five hospitals.[6]

Albrecht et al[5] compared the filtration efficiency of five new forced-air warmer intake filters with five used intake filters of an older design. Baker et al[8] and Bernards et al[10] examined only a single forced-air warmer. Investigators thoroughly described the methods used to gather air and surface samples. The study by Bernards et al[10] was not a description of an SSI outbreak but of an outbreak of *Acinetobacter baumannii* in an intensive care unit. The strain researchers cultured from affected patients was the same strain cultured from the dust filters of the forced-air warmer used in the affected patient rooms. The authors also noted that staff members were not changing the unit filters per the manufacturer's instructions. The presence of bacteria in or on these devices is a surrogate for SSI incidence; it does not establish a causal relationship to SSIs because the incidence of SSIs in subjects warmed by a forced-air warmer was not examined.

The second indirect method used[12,15,17-19] to determine whether forced-air warmers are likely to cause SSIs was to examine bacterial counts near or on patients[12,15,18] or volunteers[17,19] or near where the site of surgery would most likely be in an empty OR[17] (Table 3). Researchers obtained samples from the surgical site,[12,15,19] near the surgical site,[17] and close to the middle of the OR.[18] The investigators clearly described the methods used to gather samples and culture bacteria. We assumed, but this was not identified in the studies, that all ORs met air handling standards. Only two studies[17,18] described the OR as using "ultra-clean" air handling. Conditions were not standardized. For example, some investigators did not include a surgical team or traffic in the OR,[17,19] and the setting for other studies[12,15] was a working OR during actual procedures.

The final indirect method used to help determine the likelihood of forced-air warmers causing SSIs was to examine unwanted airflow disturbances caused by the air emitted from the forced-air warmer cover placed on the patient (Table 4).[9,11,13,14,16,17]

TABLE 2. Summary of Evidence: Incidence of Forced-Air Warmers Harboring Organisms

Evidence source[a]	Number of devices examined	Culture sites	Findings	Comments[b]
Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? *Orthop Rev (Pavia)*. 2009;1(2):e28.	■ 25 forced-air warming systems[c,d] from 5 hospitals	■ Air from intake and output hoses, interior of intake and output hoses	■ 8 of 25 forced-air warming systems had lower filtration efficiencies ■ 17 forced-air warming systems had bacteria cultured from inside 71% of intake and 88% of output hoses ■ 9 forced-air warming systems had 89% positive cultures from the liquid from rinsing the inside of the output hose	■ Implied forced-air warming systems emitting internally generated contamination within the size range of free-floating bacteria (< 4 µm)
Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: an evaluation of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control*. 2011;39(4):321-328.	■ 52 forced-air warming systems[c] ■ 5 new intake filters[c] ■ 5 used intake filters[c]	■ Internal air path surfaces, hose outlet particle counts	■ Newer filters had 93.8% retention efficiency ■ Used filters had 61.3% retention efficiency ■ 92.3% of forced-air warming system blowers had bacteria cultured from internal air path surfaces	■ Increased efficiency of new filters may be because of design change ■ Approximately 58% of forced-air warming blowers were internally generating and emitting airborne contaminants
Avidan MS, Jones N, Ing R, Khoosal M, Lundgren C, Morrell DF. Convection warmers—not just hot air. *Anaesthesia*. 1997;52(11):1073-1076.	■ 10 forced-air warming systems[e] from various ORs	■ Multiple locations	■ 4 out of 10 forced-air warming systems' output hoses harbored potentially pathogenic organisms ■ 10 out of 10 showed no growth from air from the forced-air warming system blanket when perforated ■ The upstream side of the filter showed evidence of colonization	■ Fitting the outlet hose with a filter may prevent emission of bacteria from forced-air warming systems

TABLE 2. *(continued)* Summary of Evidence: Incidence of Forced-Air Warmers Harboring Organisms

Evidence source[a]	Number of devices examined	Culture sites	Findings	Comments[b]
			■ Organisms included *Staphylococcus epidermidis* ■ There was no organism growth when the output hose was fitted with a filter[f]	
Baker N, King D, Smith EG. Infection control hazards of intra-operative forced air warming. *J Hosp Infect*. 2002;51(2):153-154.	■ 1 device[g]	■ The interior and exterior of the forced-air warming systems and the inside of the output hose	■ "Heavy growth" of bacteria was obtained from all sites	
Bernards AT, Harinck HI, Dijkshoorn L, van der Reijden TJ, van den Broek PJ. Persistent *Acinetobacter baumannii*? Look inside your medical equipment. *Infect Cont Hosp Epidemiol*. 2004;25(11): 1002-1004.	■ 1 device[c]	■ The exterior and internal forced-air warming system filters	■ The same strain of *Acinetobacter baumannii* caused an outbreak ■ The organism was not cultured after the dust inside the forced-air warming systems was removed	■ The study was part of an investigation of an *Acinetobacter baumannii* outbreak in a medical intensive care unit
Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? *Crit Care*. 2003; 7(3):R13-R16.	■ Unknown number of ORs and unknown number of forced-air warming systems ■ 16 patients undergoing aortic surgery with prosthetic graft (mean 234 minutes, range 180-270 minutes)	■ Forced-air warming systems[c] with upper body cover ■ 6 sites including around the OR, near the axilla, near the wound edge, forced-air warming system[c] filter, and output hose at various times during the procedure	■ Decrease in bacterial counts at all 6 sites	■ No mention of the air handling method used in the OR, but presumably it met standards

[a] All studies were Level IV C evidence
[b] No mention of sample size calculation or whether forced-air warming systems were maintained according to the manufacturer's instructions
[c] Bair Hugger®
[d] Unknown forced-air warming system manufacturer, forced-air warming systems, or forced-air warmer
[e] 9 Bair Hugger systems, 1 Warm Touch™
[f] DAR Hygrobac filter™ for breathing systems
[g] WarmAir®

Bair Hugger is a registered trademark of Arizant Healthcare, Eden Prairie, MN. Warm Touch and DAR Hygrobac filter are trademarks of Covidien, Mansfield, MA. WarmAir is a registered trademark of Cincinnati Sub-Zero, Cincinnati, OH.

TABLE 3. Summary of Evidence: Bacterial Counts Near or on Patients, Volunteers, or Manikins During Forced-Air Warmer Use

Evidence source[a]	Setting and subjects	Interventions	Sites sampled	Findings	Comments[b]
Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger® patient warming system in prolonged vascular surgery: an infection risk? *Crit Care.* 2003;7(3): R13-R16.	■ Unknown number of ORs	■ 16 patients undergoing aortic surgery with prosthetic graft (ie, mean 234 minutes, range 180-270 minutes) ■ Forced-air warming system[c] with upper body cover	■ 6 sites including around the OR, near the axilla, and near the wound edge ■ Filters and output hoses were sampled at various times during the procedure	■ Significant decrease in colony forming unit (CFU) counts at sites around the OR and near the axilla ■ The forced-air warming system filters and the wound edge were found to be sterile	■ There was no mention of the air handling method used in the OR, although it presumably met standards
Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect.* 2009;73(1):58-63.	■ 3 ORs	■ 30 total patients undergoing hip arthroplasty (ie, mean procedure time: 90 minutes) ■ 20 patients had a forced-air warming system[c] cover placed, but the study did not indicate where	■ 6 sites including around the OR, near the axilla, and near the wound edge ■ Forced-air warming system filter and output hose were sampled at various times during procedure	■ Although bacterial loads increased at some locations near the OR bed with the use of forced-air warming, the increase was comparable to or lower than the load present at the time the patient was placed on the OR bed	■ Validated air sampling method
Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002; 84(4):486-488.	■ Laminar flow ultra-clean-air—ventilated OR	■ 12 different conditions ranging from an empty OR to 4 different volunteers on the OR bed covered with the forced-air warming blanket system[d] with the unit on and off	■ 30 cm from a simulated operating site	■ No detectable airborne contamination was detected at the sample site with any condition	■ This pilot study showed low levels of CFU/m^3 ■ 3 of the 4 volunteers had varying degrees of psoriasis ■ There was no surgical team or traffic in the OR
Tumia N, Ashcroft GP. Convection warmers—a possible source of contamination in	■ 2 ultra-clean-air—ventilated ORs	■ 2 collection periods in an empty OR ■ 4 collection periods during orthopedic procedures	■ Close to the middle of the OR, 1 m off of the floor	■ Nonsignificant increase in CFUs with a forced-air warming system on ($P = .48$)	■ Unknown patient characteristics ■ Unknown where the forced-air warming system

TABLE 3. *(continued)* Summary of Evidence: Bacterial Counts Near or on Patients, Volunteers, or Manikins During Forced-Air Warmer Use

Evidence source[a]	Setting and subjects	Interventions	Sites sampled	Findings	Comments[b]
laminar airflow operating theatres? *J Hosp Infect*. 2002; 52(3):171-174.		■ A forced-air warming system cover was applied to the patient		compared with when it was off	cover was applied ■ Unknown forced-air warming system manufacturer, CFUs, forced-air warming system, forced-air warmer, or OR
Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. *Anesth Analg*. 1993;76(1):50-53.	■ 3 ORs	■ 8 draped volunteers as simulated patients ■ Lower body forced-air warming blanket system[c] ■ 2 study periods: 2 hours forced-air warming system off, 2 hours forced-air warming system on	■ Abdomen	■ No difference in total number of bacterial colonies between two study periods ■ More coagulase negative colonies when the forced-air warming system was off ($P < .05$)	■ OR air handling presumably met standards ■ Volunteers had normal skin and were not taking antibiotics ■ Skin was not prepped ■ There was no surgical team or traffic in the OR

[a] *All studies were Level IV C evidence*
[b] *No mention of sample size calculation or whether forced-air warming systems were maintained according to manufacturer instructions*
[c] *Bair Hugger®*
[d] *Warm Touch™*
Bair Hugger is a registered trademark of the Arizant Healthcare, Eden Prairie, MN. Warm Touch™ is a trademark of Covidien, Mansfield, MA.

Forced-air warmers may interrupt the flow of filtered air toward the area of the wound and may allow dust particles containing pathogenic organisms to come into contact with the wound. To study airflow disturbances, the researchers used different methods:

- Sessler et al[16] and Sharp et al[17] examined airflow using smoke,
- Belani et al[9] and McGovern et al[14] used neutral-buoyancy air bubbles,
- Legg et al[13] and Sessler et al[16] used particle counts, and
- Dasari et al[11] and Legg et al[13] measured air temperature at various heights in the OR.

The methods were well described by the investigators, but only two of the investigators[14,16] described methods to detect airflow disturbances that followed an existing standard[16] or used a previously validated method.[14] None of these studies were conducted when a patient was undergoing a procedure but were performed under controlled conditions, including having no traffic in the OR.

DISCUSSION

The evidence we reviewed does not conclusively indicate that forced-air warmers are a cause of SSIs. The lack of conclusive evidence is mainly

TABLE 4. Summary of Evidence: Unwanted Airflow Disturbances in the OR Caused by the Forced-Air Warmer

Evidence source[a]	Setting, subjects, and intervention	Assessment of airflow disturbance	Findings	Comments[b]
Belani KG, Albrecht M, McGovern PD, Reed M, Nachtsheim C. Patient warming excess heat: the effects on orthopedic operating room ventilation performance. *Anesth Analg*. 2013; 117(2):406-411.	■ Downward displacement in ventilated OR ■ Manikin draped for total knee replacement procedure ■ Forced-air warmer[c] with torso cover, torso conductive fiber blanket,[d] or no warming device ■ Experiment repeated once	■ Neutral-buoyancy detergent bubbles were released under the drape near the head of the manikin and sampled over the surgical site	■ There was an increase in average bubble counts over the surgical site with the forced-air warmer (132.5) compared with the conductive fiber blanket (0.48) ($P < .003$)	■ Motionless anesthesia professional at the head of the OR bed ■ No simulated OR team or traffic ■ Use of bubbles to follow airflow
Dasari KB, Albrecht M, Harper M. Effect of forced-air warming on the performance of operating theatre laminar flow ventilation. *Anaesthesia*. 2012;67(3):244-249.	■ Partial-walled, ultra-clean OR ■ Manikin draped for an abdominal procedure ■ Lower body forced-air warmer,[c] over-body conductive fiber blanket,[d] under-body resistive blanket[e]	■ Air temperature measured at 5 heights, including the floor, OR bed, patient, ceiling at 5 locations, and above the surgical site	■ There was a greater increase in temperature over the surgical site with the forced-air warmer: 2.7°C (4.9°F) ($P < .001$) higher than the conductive fabric and 3.6°C (6.5°F) ($P < .001$) higher than the resistive blanket	■ Based on changes in air temperature at various locations, the authors concluded that the forced-air warmer generates convection currents near the surgical site and may produce unwanted airflow disturbances
Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone Joint Surg Br*. 2012;94(2): 254-256.	■ Orthopedic OR ■ 1 draped volunteer used to simulate a lower-limb procedure ■ Torso forced-air warmer cover[c] or torso conductive fiber blanket[d]	■ Particle counts (size 0.3, 0.5, 5 µm) 10 cm above the surgical site ■ Air temperature at various locations in the OR	■ Particle counts increased with the forced-air warmer compared with the conductive fiber blanket ($P = .0038$ to .0087)	■ Use of wall extensions to maximize airflow ■ A surgeon with a hood and body exhaust system but no other team members
McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics.	■ Laminar flow ultra-clean-air—ventilated OR ■ Draped manikin simulating hip replacement (repeated once) and draped lumbar spinal procedure (not repeated)	■ Neutral-buoyancy detergent bubbles were released near the manikin's head or near the floor ■ The area near the surgical site was observed	■ Air currents with the forced-air warmer on were more toward the surgical site compared with the conductive fabric	■ Single surgeon and anesthesia professional, but no OR traffic

TABLE 4. *(continued)* Summary of Evidence: Unwanted Airflow Disturbances in the OR Caused by the Forced-Air Warmer

Evidence source[a]	Setting, subjects, and intervention	Assessment of airflow disturbance	Findings	Comments[b]
J Bone Joint Surg Br. 2011;93(11):1537-1544.	■ Upper or lower body forced-air warmer[c] cover or torso conductive fabric blanket[d]			
Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. *Anesth Analg*. 2011; 113(6):1416-1421.	■ Two laminar flow ORs ■ Draped volunteer patient ■ Warmed manikins represented surgical team members ■ Forced-air warmer[c] with upper body cover or under-body blanket	■ Smoke with visual tracer	■ There was no impairment in laminar flow and there were no unwanted airflow disturbances with either the forced-air warmer with upper body cover or under-body blanket.	■ No OR traffic
Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002;84(4): 486-488.	■ Laminar flow ultra-clean-air–ventilated OR ■ 12 different conditions ranging from empty OR to 4 different volunteers on OR beds covered with forced-air warmer[f] blankets	■ Smoke test	■ There was no significant effect on OR airflow with the forced-air warmer[b] unit on or off	■ No OR traffic

[a] *All studies were Level IV C evidence*
[b] *No mention of sample size calculation or whether forced-air warmers were maintained according to manufacturer instructions*
[c] *Warm Touch™*
[d] *Bair Hugger®*
[e] *Hot Dog Total Access Warming™*
[f] *Inditherm™*
Warm Touch is a trademark of Covidien, Mansfield, MA. Bair Hugger is a registered trademark of Arizant Healthcare, Eden Prairie, MN. Hot Dog Total Access Warming is a trademark of Augustine Temperature Management, Eden Prairie, MN. Inditherm is a registered trademark of Inditherm PLC Corp, Rotherham, England.

because of methodological problems in the investigations, such as a general lack of randomization, methods to determine an adequate sample size, and blinding. Only three[12,14,15] of the 15 investigations[5-19] followed patients who were warmed with a forced-air warmer to determine the incidence of SSI. The majority of the investigations indirectly examined the PICO question by determining whether the forced-air warmer harbored organisms, there was an increase in bacteria on or near the surgical site, or the forced-air warmer caused an unwanted airflow disturbance that could lead to an increase in bacteria entering the wound.

Two[12,15] of the three investigations[12,14,15] that followed subjects on whom a forced-air warmer had been used during surgery did not report an increase in SSIs with forced-air warmer use. These investigators reported there were no SSIs in a small

number of patients who underwent major vascular surgery with prosthetic graft use (ie, 16 patients)[12] or patients who underwent hip arthroplasty (ie, 30 patients)[15] regardless of whether a forced-air warmer was used intraoperatively. Serious methodological problems included the lack of a control group[12] and no description of the length of the follow-up period.[15] A third investigation[14] had a respectable sample size of 1,437 patients undergoing major joint replacement surgery, but more than half of the patients were in the forced-air warmer group. These investigators reported there was a greater risk of an SSI in subjects on whom a forced-air warmer was used intraoperatively (odds ratio, 3.8; $P = .024$). However, potentially serious problems with this study included the disclosure that one or more of the authors had been or was supported by a commercial party that manufactures a competing product.

The remaining three methods indirectly examined the PICO question. With the first indirect method, the findings of five[5-8,10] of the six[5-8,10,12] investigations suggested the forced-air warmer could be harboring bacteria or bacteria-containing particles. Typically researchers took swabs from various locations inside of the forced-air warmer, including the filter, air path, and output hose, and transferred the swabs to culture media manually or by blowing air from the unit directly onto culture plates. The investigators cultured bacteria from these sites and concluded that forced-air warmers could be a cause of SSIs. Two of these investigations[5,6] also concluded that there is a risk of the forced-air warmer emitting particles capable of carrying bacteria. In the investigation indicating that the forced-air warmer did not likely harbor bacteria,[12] the investigators reported there were no bacteria cultured from the output hose and filter. The problems with these investigations[5-8,10,12] were that there was no mention of how the forced-air warmers were maintained and researchers established no causal link between the presence of bacteria in the forced-air warmer and SSIs.

Another group of studies[12,15,17-19] looked at the presence of bacteria near or on volunteers, manikins, or patients when using a forced-air warmer, and none conclusively showed an increase in bacteria. Sharp et al[17] found that there was no airborne contamination regardless of whether a forced-air warmer was used. Zink and Iaizzo[19] found that there was no difference in bacteria counts. Tumia and Ashcroft[18] found an insignificant increase. Huang et al[12] found a significant decrease in colony counts when using a forced-air warmer. The fifth group of investigators, Moretti et al,[15] concluded that although the bacterial loads were increased at some locations when using a forced-air warmer, the increase was no higher than the bacterial load seen at the time the patient was assisted onto the OR bed. None of these investigators reported a conflict of interest.

The final indirect method sought to determine whether forced-air warmers cause unwanted airflow disturbances that encourage bacteria to be blown toward the surgical site. None of these investigations were conducted during actual surgical procedures.[9,11,13,14,16,17] Instead, the researchers used highly controlled simulated

AORN Resources

- Clinical FAQs: Hypothermia. AORN, Inc. *http://www.aorn.org/clinicalfaqs.*
- Periop Mastery Program: Preventing unplanned perioperative hypothermia. AORN, Inc. *http://www.aorn.org/periopmasteryprogram.*
- Recommended practices for the prevention of unplanned perioperative hypothermia. In: *Perioperative Standards and Recommended Practices.* Denver, CO: AORN, Inc; 2013:375-386.

Web site access verified August 5, 2013.

scenarios that did not realistically simulate movement and traffic in the OR. Four[9,11,13,14] of the groups of investigators concluded that forced-air warmers were likely to cause these unwanted airflow disturbances. At least one author in all four investigations had been or was currently supported by a company manufacturing a leading competitor to forced-air warmers. No definitive causal link was established between the airflow disturbances and SSIs. Additionally, one study[16] indicating there was no unwanted airflow disturbance was supported, in part, by a forced-air warmer manufacturer; and one of the investigators received support from a forced-air warmer manufacturer.

NURSING IMPLICATIONS

We found no randomized clinical trials examining whether there is an increase in SSIs in subjects on whom a forced-air warmer is used intraoperatively. All of the studies we appraised for this review had major methodological problems, such as the possibility of an inadequate sample size, lack of blinding, and not maintaining the devices according to the manufacturer's instructions. In the three investigations that followed subjects on whom a forced-air warmer had been used during surgery,[12,14,15] only one[14] concluded there was an increase in SSI with forced-air warmer use; however, not only was there no randomization or blinding in that investigation, there was no control of potentially confounding factors, and it is not known what effect history played on the results because the data were collected during the two-year study period.

RECOMMENDATIONS

Although concerns exist about the potential SSI risk from using forced-air warming units, clinicians should continue to use these devices because they are effective for preventing inadvertent perioperative hypothermia.[20] Clinicians should continue to use these devices so long as they are meticulously maintained according to the manufacturer's instructions, including properly replacing filters. Clinicians should take steps to prevent health care–associated infections from the use of forced-air warmers, just as they should when using any medical device. For instance, personnel should routinely and meticulously clean forced-air warmers with manufacturer-approved products, and these devices should be used strictly according to the manufacturer's instructions. Manufacturers should explore designs that allow for convenient cleaning of the surfaces of the airflow path.

FUTURE RESEARCH

The question of forced-air warmers causing SSIs should be examined in large, multicenter, randomized, controlled trials that are free from potential sources of bias such as funding by competing manufacturers. Observers should be blinded as much as possible and sample sizes should be based on the results of existing, albeit flawed, investigations. Investigators should include similar control and treatment groups with similar antibiotic use and surgical techniques. Until the findings of such rigorous studies are reported, clinicians should continue to use forced-air warmers.

CONCLUSION

Forced-air warming devices are an efficacious method of preventing intraoperative hypothermia and its complications (eg, coagulopathy, SSI).[20] Despite this efficacy, there may be provider hesitation in using these devices because of concerns related to these devices acting as vectors of infection or causing unwanted airflow disturbances that result in SSIs.[2]

Our review uncovered no conclusive evidence that the use of forced-air warmers increases the risk of SSIs. Although there is evidence that bacteria may be harbored on the air path surfaces inside the forced-air warmer, the studies that we appraised failed to establish a causal link between this and an increase in SSIs. The evidence also does not support the concern that use of a forced-air warmer may cause an increase in bacteria near or on the patient or cause unwanted airflow disturbances. These findings confirm the AORN

recommendations that forced-air warming is an effective way to prevent unplanned perioperative hypothermia.[20] AORN

***Editor's notes**: PubMed is a registered trademark of the US National Library of Medicine, Bethesda, MD. Academic Search Complete is a trademark of EBSCO Industries, Birmingham, AL.*

References

1. Sessler DI. Temperature monitoring and perioperative thermoregulation. *Anesthesiology.* 2008;109(2):318-338.
2. Weirich TL. Hypothermia/warming protocols: why are they not widely used in the OR? *AORN J.* 2008;87(2): 333-344.
3. Richardson WS, Wilson MC, Nishikawa J, Hayward RS. The well-built clinical question: a key to evidence-based decisions. *ACP J Club.* 1995;123(3):A12-A13.
4. Stetler CB, Morsi D, Rucki S, et al. Utilization-focused integrative reviews in a nursing service. *Appl Nurs Res.* 1998;11(4):195-206.
5. Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: an evaluation of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control.* 2011;39(4):321-328.
6. Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? *Orthop Rev (Pavia).* 2009;1(2):e28.
7. Avidan MS, Jones N, Ing R, Khoosal M, Lundgren C, Morrell DF. Convection warmers—not just hot air. *Anaesthesia.* 1997;52(11):1073-1076.
8. Baker N, King D, Smith EG. Infection control hazards of intraoperative forced air warming. *J Hosp Infect.* 2002; 51(2):153-154.
9. Belani KG, Albrecht M, McGovern PD, Reed M, Nachtsheim C. Patient warming excess heat: the effects on orthopedic operating room ventilation performance. *Anesth Analg.* 2013;117:406-411.
10. Bernards AT, Harinck HI, Dijkshoorn L, van der Reijden TJ, van den Broek PJ. Persistent Acinetobacter baumannii? Look inside your medical equipment. *Infect Cont Hosp Epidemiol.* 2004;25(11):1002-1004.
11. Dasari KB, Albrecht M, Harper M. Effect of forced-air warming on the performance of operating theatre laminar flow ventilation. *Anaesthesia.* 2012;67(3):244-249.
12. Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? *Crit Care.* 2003;7(3):R13-R16.
13. Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone Joint Surg Br.* 2012;94(2):254-256.
14. McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. *J Bone Joint Surg Br.* 2011;93(11):1537-1544.
15. Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect.* 2009;73(1):58-63.
16. Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. *Anesth Analg.* 2011;113(6):1416-1421.
17. Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002;84 (4):486-488.
18. Tumia N, Ashcroft GP. Convection warmers—a possible source of contamination in laminar airflow operating theatres? *J Hosp Infect.* 2002;52(3):171-174.
19. Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. *Anesth Analg.* 1993;76(1):50-53.
20. Recommended practices for the prevention of unplanned perioperative hypothermia. In: *Perioperative Standards and Recommended Practices.* Denver, CO: AORN, Inc; 2013:375-386.

Melissa D. Kellam, DNAP, CRNA, is a staff CRNA at the Mobile Infirmary, Mobile, AL, and a clinical coordinator, Graduate Programs of Nurse Anesthesia, at Texas Wesleyan University, Ft Worth, TX. *Dr Kellam has declared no affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Loraine S. Dieckmann, PhD, is an associate professor of pharmacology, Graduate Programs of Nurse Anesthesia, at Texas Wesleyan University, Ft Worth, TX. *Dr Dieckmann has declared no affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

Paul N. Austin, PhD, CRNA, is a professor, Graduate Programs of Nurse Anesthesia, at Texas Wesleyan University, Ft Worth, TX. *Dr Austin has declared no affiliation that could be perceived as posing a potential conflict of interest in the publication of this article.*

EXAMINATION

CONTINUING EDUCATION PROGRAM

3.0 CE

www.aorn.org/CE

Forced-Air Warming Devices and the Risk of Surgical Site Infections

PURPOSE/GOAL

To provide knowledge specific to the use of forced-air warming systems and surgical site infections.

OBJECTIVES

1. Describe inadvertent perioperative hypothermia.
2. Discuss the use of forced-air warming to maintain normothermia perioperatively.
3. Describe the methodologies used in the studies appraised in this article.
4. Describe the authors' conclusions about the use of forced-air warming systems.

The Examination and Learner Evaluation are printed here for your convenience. To receive continuing education credit, you must complete the Examination and Learner Evaluation online at *http://www.aorn.org/CE*.

QUESTIONS

1. Inadvertent perioperative hyperthermia is the most common thermal disturbance seen in surgical patients.
   a. true *b.* false
2. Reasons for heat loss during operative and invasive procedures include
   1. the patient's exposure to the surgical environment.
   2. the effects of anesthetic agents and medications that interfere with temperature regulation.
   3. redistribution of heat from the core to the periphery of the body.

   a. 1 and 2 *b.* 1 and 3
   c. 2 and 3 *d.* 1, 2, and 3
3. Health care providers often use forced-air warming systems to provide surface warming in the OR because these devices are helpful in maintaining normothermia and preventing hypothermia.
   a. true *b.* false
4. Health care providers are concerned about the use of forced-air warming systems because
   a. of the cost that the health care facility must assume to use the units.
   b. of the potential for increasing the risk of surgical site infections (SSIs).
   c. they are difficult to use and interfere with work flow in the OR.
   d. they are noisy and cause distraction in the OR.
5. What were the methodological concerns the authors found in the studies they reviewed for this article?
   1. Researchers did not describe how they determined sample sizes of forced-air warmers or the number of study participants.

2. Researchers did not indicate whether the forced-air warmers had been maintained according to the manufacturer's instructions.
3. There was no blinding or random allocation of participants to study groups.
4. In some cases, an author of the study was or had been supported by a company that manufactures a competing product to the forced-air warmer.
5. The statistics had been incorrectly calculated.

a. 4 and 5 *b.* 1, 2, and 3
c. 1, 2, 3, and 4 *d.* 1, 2, 3, 4, and 5

6. In the three investigations that followed patients who were warmed intraoperatively for SSIs, it is unknown whether the groups were similar in confounding variables such as

1. obesity.
2. age.
3. incontinence.
4. fitness for surgery.

a. 1 and 2 *b.* 3 and 4
c. 1, 2, and 3 *d.* 1, 3, and 4

7. The first method that researchers used to indirectly examine whether forced-air warmers are likely to cause SSIs included

1. swabbing the interior and exterior of one forced-air warmer.
2. comparing the filtration efficiency of five new forced-air warmer intake filters with five used filters.
3. culturing *Acinetobacter baumannii* from the nares of patients who would be undergoing surgery with a forced-air warmer.
4. swabbing used patient blankets.

a. 1 and 2 *b.* 3 and 4
c. 1, 2, and 3 *d.* 1, 2, 3, and 4

8. The second indirect method used to determine whether forced-air warmers are likely to cause SSIs was to examine bacterial counts

1. close to the middle of the OR.
2. near the surgical site.
3. on the hands of the anesthesia professional.
4. on or near patients or volunteers.

a. 1 and 2 *b.* 3 and 4
c. 1, 2, and 4 *d.* 1, 2, 3, and 4

9. The evidence reviewed for this article did not conclusively indicate that forced-air warmers are a cause of SSIs because of methodological problems with the investigations.

a. true *b.* false

10. Although concerns exist about the potential SSI risk from using forced-air warming units, clinicians should continue to use these devices so long as

1. the units are meticulously cleaned with manufacturer-approved products.
2. personnel properly replace the filters.
3. clinicians take steps to prevent health care–associated infections.
4. the units are used strictly according to the manufacturer's instructions.

a. 1 and 3 *b.* 2 and 4
c. 1, 2, and 3 *d.* 1, 2, 3, and 4

LEARNER EVALUATION

CONTINUING EDUCATION PROGRAM

3.0 CE

www.aorn.org/CE

Forced-Air Warming Devices and the Risk of Surgical Site Infections

This evaluation is used to determine the extent to which this continuing education program met your learning needs. Rate the items as described below.

OBJECTIVES

To what extent were the following objectives of this continuing education program achieved?

1. Describe inadvertent perioperative hypothermia.
   Low 1. 2. 3. 4. 5. High
2. Discuss the use of forced-air warming to maintain normothermia perioperatively.
   Low 1. 2. 3. 4. 5. High
3. Describe the methodologies used in the studies appraised in this article.
   Low 1. 2. 3. 4. 5. High
4. Describe the authors' conclusions about the use of forced-air warming systems.
   Low 1. 2. 3. 4. 5. High

CONTENT

5. To what extent did this article increase your knowledge of the subject matter?
   Low 1. 2. 3. 4. 5. High
6. To what extent were your individual objectives met? *Low 1. 2. 3. 4. 5. High*
7. Will you be able to use the information from this article in your work setting? *1. Yes 2. No*
8. Will you change your practice as a result of reading this article? (If yes, answer question #8A. If no, answer question #8B.)

8A. How will you change your practice? *(Select all that apply)*

1. I will provide education to my team regarding why change is needed.
2. I will work with management to change/implement a policy and procedure.
3. I will plan an informational meeting with physicians to seek their input and acceptance of the need for change.
4. I will implement change and evaluate the effect of the change at regular intervals until the change is incorporated as best practice.
5. Other: _____

8B. If you will not change your practice as a result of reading this article, why? *(Select all that apply)*

1. The content of the article is not relevant to my practice.
2. I do not have enough time to teach others about the purpose of the needed change.
3. I do not have management support to make a change.
4. Other: _____

9. Our accrediting body requires that we verify the time you needed to complete the 3.0 continuing education contact hour (180-minute) program: _____

EXHIBIT DX17

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

THE ORTHOPAEDIC FORUM

Forced Air Warming Devices in Orthopaedics: A Focused Review of the Literature

Robby S. Sikka, MD, and Richard C. Prielipp, MD, MBA, FCCM

Peer Review: This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

The current focus on maintaining normal body temperature in the operating room makes the use of patient warming devices routine—or even mandatory—in many hospitals. Forced air warming devices such as the Bair Hugger (3M Healthcare, St. Paul, Minnesota) maintain or increase core temperature in patients during the perioperative period, with benefits that include reduced surgical wound infections, maintenance of normal coagulation, and faster discharge from the post-anesthesia care unit (PACU)[1-5]. However, some recent literature has raised concerns regarding a possible increased risk of deep surgical site infections specifically associated with the use of the forced air warming systems in the orthopaedic operating room[5-12]. One concern is that a convective device could disrupt unidirectional downward laminar airflow, which may be especially critical in joint arthroplasty operating rooms. This concern is based on theoretical mechanisms, laboratory simulations, retrospective case series, and studies showing potentially pathogenic organisms growing in the hoses and filters of forced air warming devices[6-12]. However, multiple other studies[13-15] and a Continuing Education statement by the Association of periOperative Registered Nurses (AORN)[16] suggest that proper use of the forced air warming devices mitigates or eliminates this risk while maximizing the benefits of patient warming. The purpose of the present manuscript is to review the current literature on the use of patient warming devices in orthopaedic surgery, specifically in joint arthroplasty.

Importance of Normothermia

Hypothermia (core body temperature, <36°C) is a constant risk during general anesthesia because of factors such as impaired thermoregulation, heat loss secondary to a cold operating room, redistribution of body heat from the core to the vasodilated periphery, and infusion of cool intravenous fluids. Major adverse consequences of perioperative hypothermia can include adrenergic activation, myocardial ischemia, thermal discomfort, decreased drug metabolism, coagulopathy and increased blood loss, wound infections, prolonged recovery room stay, and increased staff and hospital costs[1,2,4,14,15]. Moreover, it is now accepted that maintaining normothermia in surgical patients substantially lowers the risk of postoperative surgical site infections[12,14,16,17]. Indeed, Kurz et al. showed that an intraoperative core body temperature decrease of only 2°C can triple the rate of soft-tissue wound infection[17]. Therefore, maintaining normothermia is a vital part of the SCIP (Surgical Care Improvement Project) measure developed by The Joint Commission and the PQRS (Physician Quality Reporting System) measure developed by the CMS (Centers for Medicare & Medicaid Services) in the U.S., and documented use of patient

Disclosure: None of the authors received payments or services, either directly or indirectly (i.e., via his or her institution), from a third party in support of any aspect of this work. None of the authors, or their institution(s), have had any financial relationship, in the thirty-six months prior to submission of this work, with any entity in the biomedical arena that could be perceived to influence or have the potential to influence what is written in this work. Also, no author has had any other relationships, or has engaged in any other activities, that could be perceived to influence or have the potential to influence what is written in this work. The complete **Disclosures of Potential Conflicts of Interest** submitted by authors are always provided with the online version of the article.

TABLE I Proper Maintenance and Use of Forced Air Warmers

Recommendations
1. The filter should be changed every 6 months or 500 hours. A counter is available on some devices (e.g., Bair Hugger 700 series) to indicate the total hours of use.
2. Calibration testing should occur every six months by biomedical engineering staff at the user's institution. The manufacturer should check or replace devices that fail calibration testing.
3. Do not warm patients with the warming unit's hose alone, as severe thermal injury may occur. Always connect the hose to a new, manufacturer-approved warming gown for each patient.
4. Do not continue warming if the red overtemperature indicator light illuminates or an audible alarm sounds, as thermal injury may result. Turn the warming unit off immediately and check the patient's skin.
5. Do not use a forced air warming device over transdermal medications; increased drug delivery and patient death or injury may result.
6. Do not allow the patient to lie on the warming unit hose or allow the hose to contact the patient's skin during patient warming.
7. Equipment is not suitable for use in the presence of a flammable anesthetic mixture (e.g., containing air, oxygen, or nitrous oxide).
8. Do not place the nonperforated side of the blanket on the patient. Thermal injury may result. Always place the perforated side (the side with small holes) toward the patient.
9. The warming device should be disconnected from the power source before cleaning. Between patients, the outside of the hose should be cleaned with a damp, soft cloth and a mild detergent or antimicrobial spray and then dried with a separate cloth.
10. If a fault occurs in the unit, unplug the temperature management unit and wait for five minutes. Reconnect the temperature management unit to a grounded power source. The unit will perform the normal power-on-reset sequence and then enter the standby mode. If the unit does not return to normal operation, contact a service technician.
11. Temperature and calibration testing should be performed every 6 months or 500 hours of use.

warming devices is a part of the requirements for receiving full reimbursement from the CMS. Any warming device may be used for the purpose of active warming intraoperatively. The goal is to maintain normothermia, or at least a body temperature of ≥36°C (≥96.8°F) recorded within the thirty minutes immediately before, or the fifteen minutes immediately after, anesthesia end time. Moreover, these normothermic goals apply to all patients, regardless of age, who are undergoing surgical procedures under general or neuraxial anesthesia lasting sixty minutes or more, although SCIP normothermia requirements are limited to colorectal procedures[18,19].

Forced air warming devices such as the Bair Hugger system rely on convective warming and definitively improve the ability of anesthesia professionals to maintain normothermia in patients undergoing abdominal and orthopaedic procedures[20-22]. Other devices (e.g., HotDog; Augustine Temperature Management, Eden Prairie, Minnesota) use conductive heating as the primary energy mechanism and may theoretically result in higher thermal efficiency compared with forced air warming[12]. The issue of rewarming patients who are already hypothermic is another challenge, as rewarming generally requires greater energy and more time compared with maintaining normothermia. Plattner et al. investigated rewarming by means of a resistive warming device (HotDog) and a forced air warming device (Bair Hugger), and they showed that core temperature increased twice as rapidly in the Bair Hugger group. The hypothermic patients randomized to forced air warming achieved a higher mean core body temperature during surgery at two, three, and four-hour time points[23].

However, Leijtens et al. showed the prevalence of hypothermia in patients undergoing major joint arthroplasty to be 26% to 28% despite the use of forced air warming, and those patients who developed hypothermia during total hip arthroplasty were 3.7 times more likely than normothermic patients to develop a periprosthetic infection[24]. Thus, maintaining normothermia during total hip arthroplasty surgery is a straightforward strategy to reduce the risk of surgical site infection—and at far less cost than the highly specialized orthopaedic laminar-air-flow operating room[25-27].

Warming Devices and Laminar Airflow

The rate of infection following joint arthroplasty involving the lower limbs is currently <1%[28]. In a multicenter study involving 8052 joint replacements, Lidwell et al. concluded that the risk of deep and superficial wound infections was substantially reduced in surgical procedures performed in operating rooms with ultraclean air ventilation compared with conventional ventilation[20]. Current ultraclean ventilation systems protect the surgical site from airborne contamination through a constant delivery of filtered air with a uniform downward velocity (0.3 to 0.5 m/s)[11,24]. This system is dependent on proper airflow volumes and temperature gradients. Unidirectional vertical airflow ventilation is more effective than horizontal ventilation, especially in combination with walls around the operating area. Body exhaust suits also reduce the number of airborne bacteria[4]. However, local sources of excess thermal energy can result in temperature gradients that interrupt the downward airflow of ultraclean air[4]. These interruptions in the velocity of downward airflow likely increase the entry of contaminants into the surgical site. Heat rising against the downward laminar airflow may also draw nonsterile contaminants up and into the surgical site.

TABLE II Alternative or Adjunctive Warming Options for Patients*

Device	Example	Benefits, Potential Risks, Contraindications
Patient warming blanket	QUINEN Warming Blanket (Shreeyash)	Covers large part of patient, making observation of skin difficult; not practical for extremity surgery
Circulating water garment	Allon ThermoWrap (MTRE)	Potential for leaking and burns as well as pressure sores; not practical for extremity surgery. Typically uses microprocessor in device
Thermal pad	Patient Warming System (Pintler)	Potential risk for cutaneous burns
Warming mattress	PerfecTemp (Medline)	Potential risk for cutaneous burns
Fluid warmer	HOTLINE (Smiths), Fluid Ranger (3M), Level 1 (Smiths)	Air emboli[40]
Reflective blanket	GRI-Alleset Healthcare or Thermoreflect patient warming products	Risk of cutaneous burns is low but may increase if combined with FAW; pressure sores may develop. Passive warming with reflective heating blankets or elastic bandages wrapped tightly around the legs were found to be ineffective in reducing the prevalence or magnitude of hypothermia[35]
Passive covering	Blanket	Increased risk of burns if used with FAW and areas of high heat develop
Conductive warming	HotDog (Augustine)	Risk of pressure sores and cutaneous burns
Forced air warming	Bair Hugger (3M)	Risk of cutaneous burns and of colonization of filter and tubing. Proper maintenance minimizes risk, and proper draping and use may decrease risk of disruption of laminar airflow

*For forced air warming (FAW) devices, the maximum contact surface temperature should not exceed 48°C, and the mean contact surface temperature should not exceed 46°C under normal conditions. For circulating liquid devices, the contact surface temperature should not exceed 43°C, and the mean contact surface temperature should not exceed 42°C under normal conditions. The fluid warming standard requires that the device does not heat the fluid above 44°C under normal conditions[41,42].

According to several recent studies, forced air warming devices may be a source of rising thermal currents that affect the normal downward airflow of laminar airflow systems[6-12]. This may raise the number of bacterial particles—as well as the temperature—over the surgical site. McGovern et al. reported an infection rate of 3.1% with use of forced air warming compared with 0.8% with a conductive warming device[12]. The authors suggested that discontinuing the forced air warming would decrease the infection rate by 74%[10,11]. Legg et al. showed that forced air warming devices increased the mean temperature and the number of particles over the surgical site, thereby increasing the number of pathogens over the surgical site[10,11]. However, several of those studies were funded by the manufacturers of competing devices[6-10,12]. Most studies on the use of forced air warming devices and other warming technologies in combination with laminar airflow are clearly underpowered and poorly controlled, and conclusions regarding the independent effect of the warming devices on surgical site contamination and infection are uncertain[15,29].

Other studies (again, usually industry-funded) have indicated that forced air warming does not increase the risk of particulate dispersion near surgical sites[13,22,30-34]. These studies have shown that perioperative temperature management with forced air warming actually decreases the risk of surgical site infection. Sessler et al.[32] conducted a simulation study similar to that of McGovern et al.[12] and showed that forced air warming did not reduce air quality in an operating room with laminar flow ventilation. No difference in infection rate was evident in a series of patients undergoing vascular, breast, and hernia surgery who were warmed with either a conductive heating or forced air warming (Bair Hugger) device. However, patients who did not have any warming device did have a higher rate of infection[27]. The authors of several systematic reviews have recommended the use of forced air warming because of its improved ability to maintain normothermia and suggested that it has little role in disrupting laminar airflow[5,31,35]. Thus, the literature appears to indicate that forced air warming can impact laminar flow under certain very specific conditions, but any actual clinical impact on surgical site infections must be considered unproven at this time. On the basis of the current evidence, it is likely that both forced air warming and conduction-based warming decrease the risk of hypothermia in orthopaedic patients undergoing arthroplasty, and maintenance of normothermia is critical to a strategy for minimizing surgical site infections. Neither type of device can completely eliminate the risk of hypothermia, and both share risks of adverse side effects such as burns and pressure sores[36]. Indeed, all medical devices require training, education, and maintenance for proper use.

TABLE III Articles Evaluating Forced Air Warming Devices*

	Albrecht 2009[7]	Albrecht 2011[6]	Belani 2013[8]	McGovern 2011[12]	Legg 2012[10]	Dasari 2012[9]	Legg 2013[11]	Reed 2013[38]
Study design	Lab. expt.	Lab. expt.	Lab. expt.	Retrospective case series	Lab. expt.	Lab. expt.	Lab. expt.	Lab. expt.
Simulated or actual patients	Simulated	Simulated	Simulated	Patients undergoing THA and TKA	Simulated	Simulated	Simulated	Simulated
No. of patients or subjects	Hospitals, n = 5. Particle counts, n = 25. Swabbing, n = 17. Rinsing, n = 9	11	2 per group	1437 with 371 treated with conductive warmer and 1066 with FAW	5	5 locations at 5 heights	5	1 hospital with 23 FAW units
End points	Particle counts	Intake filter retention efficiency/ performance, airborne particles, FAW colonization	Bubble count over the simulated surgical site	Infection	Particle counts and temp. over surgical site	Temp. at simulated surgical site	Airflow visualization, drape temp., and particle entrainment	Intake filter efficiency/ performance and air path microbial colonization
Statistical significance	No	No	Yes	Yes	Yes	Yes	Yes	No
Summary of findings	FAW equipment design is questionable with respect to its ability to prevent airborne contamination	58% of FAW units were found to generate airborne contamination. No direct link between infection and FAW. New filters may improve efficiency	FAW disrupted laminar airflow; disruption was dependent on the exact setup of the room	High risk of developing deep infections with FAW use (odds ratio = 3.8, p = 0.024)	Temp. over surgical site and the no. of particles were greater with FAW. Unable to definitively conclude that these are causes of infection	Greater temp. over the surgical site with FAW vs. conductive warming and resistive blanket	Disruption of laminar airflow and increased no. of particles over the surgical site with FAW. Drape temp. also increased. Authors suggested certain OR setups may impact laminar flow	Filter efficiency was 64% in lab. experiments but filters performed within specifications in the OR. 70% of FAW units had higher particle counts at the hose end compared with the intake
Study limitations	Testing was done without the blanket, which is required for proper airflow. Did not demonstrate that detected particles were bacteria. Author conflict of interest	Testing was done without the blanket, which is required for proper airflow. No demonstration of proper maintenance of filters and FAW units. Author conflict of interest	Did not control for room setup. Author conflict of interest	Coauthor was employee of conductive warming company. Did not account for age or medical comorbidities. Assumed causation. Did not account for other infection control measures implemented during study period	Did not simulate OR traffic and personnel	Assumed higher temp. at surgical site increases risk of infection. Did not simulate normal OR traffic. Author conflict of interest	No direct relationship shown between laminar airflow being affected and increased bacteria over surgical site	Relied on particle counts rather than sampling of microorganisms from hose-end airflow. High percentage of control swab contamination (50%). Testing was done without blanket

*THA = total hip arthroplasty, TKA = total knee arthroplasty, FAW = forced air warming, OR = operating room, ICU = intensive care unit, and CFU = colony-forming unit.

Proper Use of Equipment and Drapes

The primary heating unit in forced air warming devices requires cleaning and routine maintenance (Table I). Delayed or deficient maintenance may result in adverse events. Gjolaj et al.[26] described the results of bacterial testing of Bair Hugger units. After six months or more than 500 hours of usage (the time at which the manufacturer recommends installation of new filters), the distal end of the outflow hose was positive for

TABLE III (*continued*)

Baker 2002[39]	Bernards 2004[37]	Huang 2003[13]	Sharp 2002[33]	Tumia 2002[22]	Sessler 2011[32]	Zink 1993[34]	Moretti 2009[31]	Avidan 1997[30]
Lab. expt.	Lab. expt.	Retrospective case series	Lab. expt.	Clinical study	Lab. expt.	Clinical study	Retrospective case series	Lab. expt.
Neither	Neither	Patients undergoing aortic surgery with prosthetic graft	Simulated	Actual patients and lab. simulation	Simulated	Actual patients but simulated surgery	Actual	Neither
1 FAW system	1 FAW system	16 patients	12 different conditions ranging from empty ORs to various volunteers with FAW	6	2	8	30 patients, 20 who received FAW and 10 who did not	10 FAW systems from ORs
Cultures of FAW hose and filter	Cultures of FAW hose and filter	Culture sites on patient and in FAW system	Assessment of laminar flow using smoke visual tracer	Increase in number of CFUs	Assessment of laminar flow using smoke visual tracer	Culture sites of abdomen	Infections and culture sites on patient and in FAW system	Cultures of filter and hose
No	No	No	No	No	No	Yes	No	No
Heavy growth of bacteria from all sites	Same strain of Acinetobacter as that responsible for an outbreak. After device was cleaned, the bacteria were not found	Decrease in bacterial counts at all 6 sites, including the axilla and the FAW system	No significant effect of FAW use on laminar airflow	Nonsignificant increase in CFUs when FAW was on compared with when it was off ($p = 0.48$)	No impairment of laminar flow and no unwanted airflow disturbances using FAW	More coagulase-negative colonies when FAW system was off ($p < 0.05$), but overall no difference in total no. of colonies between when it was on and off	No postoperative infections	40% of FAW system hoses had potentially pathogenic organisms. 100% showed no growth from the air when the FAW system blanket was worn
Only a single device was tested	Only a single device was tested. The study was a part of an investigation into an Acinetobacter outbreak in the ICU	Small number of patients. No mention of air handling method in the OR	Did not simulate normal OR traffic	Unknown patient characteristics. Unknown manufacturer of FAW system	Did not simulate normal OR traffic	Skin was not prepped. No surgical team was present and no surgery was performed on patients. Only skin flora was assessed	Unknown follow-up period. Unknown location of FAW cover. Small no. of patients	Positive cultures from tubing may not be associated with infection in the patient

bacterial growth in twelve of twenty-nine units, and the filter was positive in three units. Routine care that included changing of the filter and cleaning of the unit was then performed, and the testing was repeated after three months. The repeat cultures of the units with a previous positive culture showed no growth in the tubing or filter. This suggests that proper maintenance of the Bair Hugger is essential to reduce the risk of infection. Other studies have also revealed measurable growth of bacteria in ventilation filters, and the authors attributed the cause of infection outbreaks to colonized filters[6,7]. Frequent maintenance of the forced air warming units and cleaning of the outside and tubing of the warming unit are required to reduce

colonization and the associated risk to the patient. Some authors even propose the addition of an HEPA (high-efficiency particulate air) antimicrobial filter to forced air warming systems, but relevant studies are lacking[30,37-39].

Legg and Hamer simulated the impact of surgical drapes and equipment on forced air warming devices and laminar flow in an operating room environment[11]. For instance, the authors noted that, depending on the arrangement of medical equipment in the operating room, forced air warming devices may be more likely than conductive warmers to disrupt laminar airflow around the surgical field. They also noted that even the use of a vertical drape between the surgical field and the anesthesia team at the head of the table affects the laminar flow. Surgical drapes placed vertically as part of the sterile surgical field may themselves be warmed by forced air warming devices, leading to accessory convection currents traveling upward and disrupting downward laminar flow. Indeed, the authors suggest that if the artificial enclosure created by the vertical drape is eliminated, the production of additional heat is less likely to be important because warm air can leave more easily. They recommend using a well-insulated surface that is not in contact with the patient to distribute the additional heat that may otherwise be transferred to the drape. The authors further recommend putting the vertical drape up before the Bair Hugger is turned on, ensuring that the Bair Hugger is properly connected to the gown with no leaks, and following all manufacturer instructions regarding the placement of the gown. Clearly, proper use of forced air warming devices and associated warming gowns is required to maximize heat transfer to the patient while minimizing heat transfer to the drapes and surrounding laminar airflow.

The risks of burns and pressure sores, even involving the nonoperatively treated extremity, increase when warming devices are not used properly. Burns can result from improper placement of the warming device or from placement of the tubing on the patient. Mayo stands, trays, and surgical equipment placed on or near a patient can limit expansion of the warming blanket or gown. This can force air into a small area and increase the risk of burns. These burns are often first or second-degree and may heal with scarring. Appropriate consultation with plastic surgeons or wound nurses may allow for prompt treatment and skin coverage as needed. There are also several alternatives or adjunctive warming devices that may be used to increase patient temperature. Some of these devices and their risks and benefits are described in Table II. Several studies have indicated that the use of these devices in addition to forced air warming increases the ability to maintain normothermia[35,40-42].

Clinical Importance

It is important to consider both the risks and benefits of warming devices when deciding how to utilize them for patients undergoing joint arthroplasty. There are medical, safety, and economic implications to the choice[43,44]. Further study is warranted to prove or disprove a causal relationship between use of forced air warming and periprosthetic joint infections (Table III). In the meantime, appropriate strategies include proper maintenance of equipment and filters to reduce bacterial colonization, appropriate placement of forced air warming blankets in accordance with manufacturer recommendations, and recognition of the potential effects of these devices on laminar airflow. Future studies will need to limit bias, include large study populations, have a consistent definition of hypothermia, carefully control associated and relevant variables (e.g., operating room traffic and antibiotic protocols), and ensure equivalent efficacy of warming in all study groups. Such studies will aid clinicians in choosing appropriate future strategies for warming. ■

NOTE: The authors acknowledge Drs. Marc Swiontkowski and Thomas Vangsness for their editorial assistance.

Robby S. Sikka, MD
TRIA Orthopaedic Center,
University of Minnesota,
8100 Northland Drive,
Minneapolis, MN 55431.
E-mail address: robbysikka@gmail.com

Richard C. Prielipp, MD, MBA, FCCM
Department of Anesthesiology,
University of Minnesota,
420 Delaware Street S.E.,
Minneapolis, MN 55455.
E-mail address: prielipp@umn.edu

References

1. Fleisher LA, Beckman JA, Brown KA, Calkins H, Chaikof EL, Fleischmann KE, Freeman WK, Froehlich JB, Kasper EK, Kersten JR, Riegel B, Robb JF, Smith SC Jr, Jacobs AK, Adams CD, Anderson JL, Antman EM, Buller CE, Creager MA, Ettinger SM, Faxon DP, Fuster V, Halperin JL, Hiratzka LF, Hunt SA, Lytle BW, Nishimura R, Ornato JP, Page RL, Riegel B, Tarkington LG, Yancy CW; American College of Cardiology; American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery); American Society of Echocardiography; American Society of Nuclear Cardiology; Heart Rhythm Society; Society of Cardiovascular Anesthesiologists; Society for Cardiovascular Angiography and Interventions; Society for Vascular Medicine and Biology; Society for Vascular Surgery. ACC/AHA 2007 guidelines on perioperative cardiovascular evaluation and care for noncardiac surgery: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Writing Committee to Revise the 2002 Guidelines on Perioperative Cardiovascular Evaluation for Noncardiac Surgery) developed in collaboration with the American Society of Echocardiography, American Society of Nuclear Cardiology, Heart Rhythm Society, Society of Cardiovascular Anesthesiologists, Society for Cardiovascular Angiography and Interventions, Society for Vascular Medicine and Biology, and Society for Vascular Surgery. J Am Coll Cardiol. 2007 Oct 23;50(17):e159-241.

2. American Society of Anesthesiologists Task Force on Postanesthetic Care. Practice guidelines for postanesthetic care: a report by the American Society of Anesthesiologists Task Force on Postanesthetic Care. Anesthesiology. 2002 Mar;96(3):742-52.

3. Mangram AJ, Horan TC, Pearson ML, Silver LC, Jarvis WR; Hospital Infection Control Practices Advisory Committee. Guideline for prevention of surgical site infection, 1999. Infect Control Hosp Epidemiol. 1999 Apr;20(4):250-78; quiz 279-80.

4. ECRI Institute. HotDog (Augustine Temperature Management) compared with Bair Hugger (Arizant Healthcare, Inc.) for maintaining body temperature during surgery [custom product brief]. Custom hotline service. 2012.

5. National Collaborating Center for Nursing and Supportive Care. The management of inadvertent perioperative hypothermia in adults. NICE clinical guidelines, no. 65. London: Royal College of Nursing (UK); 2008.

6. Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: an evaluation of filtration adequacy and airborne contamination emissions in the operating room. Am J Infect Control. 2011 May;39(4):321-8. Epub 2010 Nov 20.

7. Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? Orthop Rev (Pavia). 2009 Oct 10;1(2):e28.

8. Belani KG, Albrecht M, McGovern PD, Reed M, Nachtsheim C. Patient warming excess heat: the effects on orthopedic operating room ventilation performance. Anesth Analg. 2013 Aug;117(2):406-11. Epub 2012 Jul 19.

9. Dasari KB, Albrecht M, Harper M. Effect of forced-air warming on the performance of operating theatre laminar flow ventilation. Anaesthesia. 2012 Mar;67(3):244-9.

10. Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? J Bone Joint Surg Br. 2012 Feb;94(2):254-6.

11. Legg AJ, Hamer AJ. Forced-air patient warming blankets disrupt unidirectional airflow. Bone Joint J. 2013 Mar;95-B(3):407-10.

12. McGovern PD, Albrecht M, Belani KG, Nachtsheim C, Partington PF, Carluke I, Reed MR. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. J Bone Joint Surg Br. 2011 Nov;93(11):1537-44.

13. Huang JK, Shah EF, Vinodkumar N, Hegarty MA, Greatorex RA. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? Crit Care. 2003 Jun;7(3):R13-6. Epub 2003 Mar 4.

14. Cheadle WG. Risk factors for surgical site infection. Surg Infect (Larchmt). 2006;7 Suppl 1:S7-11.

15. Kim YS, Jeon YS, Lee JA, Park WK, Koh HS, Joo JD, In JH, Seo KW. Intraoperative warming with a forced-air warmer in preventing hypothermia after tourniquet deflation in elderly patients. J Int Med Res. 2009 Sep-Oct;37(5):1457-64.

16. Kellam MD, Dieckmann LS, Austin PN. Forced-air warming devices and the risk of surgical site infections. AORN J. 2013 Oct;98(4):354-66; quiz 367-9.

17. Kurz A, Sessler DI, Lenhardt R; Study of Wound Infection and Temperature Group. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. N Engl J Med. 1996 May 9;334(19):1209-15.

18. Lehtinen SJ, Onicescu G, Kuhn KM, Cole DJ, Esnaola NF. Normothermia to prevent surgical site infections after gastrointestinal surgery: holy grail or false idol? Ann Surg. 2010 Oct;252(4):696-704.

19. Kurz A. Thermal care in the perioperative period. Best Pract Res Clin Anaesthesiol. 2008 Mar;22(1):39-62.

20. Lidwell OM, Elson RA, Lowbury EJL, Whyte W, Blowers R, Stanley SJ, Lowe D. Ultraclean air and antibiotics for prevention of postoperative infection. A multicenter study of 8,052 joint replacement operations. Acta Orthop Scand. 1987 Feb;58(1):4-13.

21. Matsukawa T, Kashimoto S, Nakamura T, Kume M, Kanda F, Kumazawa T. Effects of a forced-air system (Bair Hugger, OR-type) on intraoperative temperature in patients with open abdominal surgery. J Anesth. 1994;8(1):25-7.

22. Tumia N, Ashcroft GP. Convection warmers—a possible source of contamination in laminar airflow operating theatres? J Hosp Infect. 2002 Nov;52(3):171-4.

23. Plattner O, Roder G, Schopper C, Roth G, Sessler DI. Comparison of forced-air and a new resistive warming device for intraoperative rewarming [abstract]. In: Proceedings of the 2010 Annual Meeting of the American Society of Anesthesiologists; 2010 Oct 16; San Diego, CA. No. A076.

24. Leijtens B, Koëter M, Kremers K, Koëter S. High incidence of postoperative hypothermia in total knee and total hip arthroplasty: a prospective observational study. J Arthroplasty. 2013 Jun;28(6):895-8. Epub 2013 Mar 20.

25. Gastmeier P, Breier AC, Brandt C. Influence of laminar airflow on prosthetic joint infections: a systematic review. J Hosp Infect. 2012 Jun;81(2):73-8. Epub 2012 May 9.

26. Gjolaj MP, Ahlbrand S, Yamout IM, Armstrong D, Brock-Utne JG. Don't forget to change the Bair Hugger filter. In: Proceedings of the 2009 Annual Meeting of the American Society Anesthesiologists; 2009 Oct 20; New Orleans, LA. No. A1168.

27. Melling AC, Ali B, Scott EM, Leaper DJ. Effects of preoperative warming on the incidence of wound infection after clean surgery: a randomised controlled trial. Lancet. 2001 Sep 15;358(9285):876-80.

28. Phillips JE, Crane TP, Noy M, Elliott TS, Grimer RJ. The incidence of deep prosthetic infections in a specialist orthopaedic hospital: a 15-year prospective survey. J Bone Joint Surg Br. 2006 Jul;88(7):943-8.

29. Smith TO, Hing CB. Is a tourniquet beneficial in total knee replacement surgery? A meta-analysis and systematic review. Knee. 2010 Mar;17(2):141-7. Epub 2009 Jul 19.

30. Avidan MS, Jones N, Ing R, Khoosal M, Lundgren C, Morrell DF. Convection warmers—not just hot air. Anaesthesia. 1997 Nov;52(11):1073-6.

31. Moretti B, Larocca AM, Napoli C, Martinelli D, Paolillo L, Cassano M, Notarnicola A, Moretti L, Pesce V. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? J Hosp Infect. 2009 Sep;73(1):58-63. Epub 2009 Jul 31.

32. Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. Anesth Analg. 2011 Dec;113(6):1416-21. Epub 2011 Sep 29.

33. Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? J Bone Joint Surg Br. 2002 May; 84(4):486-8.

34. Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. Anesth Analg. 1993 Jan;76(1):50-3.

35. Moola S, Lockwood C. Effectiveness of strategies for the management and/or prevention of hypothermia within the adult perioperative environment. Int J Evid Based Healthc. 2011 Dec;9(4):337-45.

36. Truell KD, Bakerman PR, Teodori MF, Maze A. Third-degree burns due to intraoperative use of a Bair Hugger warming device. Ann Thorac Surg. 2000 Jun;69(6):1933-4.

37. Bernards AT, Harinck HI, Dijkshoorn L, van der Reijden TJ, van den Broek PJ. Persistent Acinetobacter baumannii? Look inside your medical equipment. Infect Control Hosp Epidemiol. 2004 Nov;25(11):1002-4.

38. Reed M, Kimberger O, McGovern PD, Albrecht MC. Forced-air warming design: evaluation of intake filtration, internal microbial buildup, and airborne-contamination emissions. AANA J. 2013 Aug;81(4):275-80.

39. Baker N, King D, Smith EG. Infection control hazards of intraoperative forced air warming. J Hosp Infect. 2002 Jun;51(2):153-4.

40. Woon S, Talke P. Amount of air infused to patient increases as fluid flow rates decrease when using the Hotline HL-90 fluid warmer. J Clin Monit Comput. 1999 May;15(3-4):149-52.

41. Standard specification for circulating liquid and forced air patient temperature management devices (ASTM F-2196–02). West Conshohocken, PA: American Society for Testing and Materials; 2002.

42. Standard specification for blood/intravenous fluid/irrigation fluid warmers (ASTM F-2172–02). West Conshohocken, PA: American Society for Testing and Materials; 2002.

43. Hooper GJ, Rothwell AG, Frampton C, Wyatt MC. Does the use of laminar flow and space suits reduce early deep infection after total hip and knee replacement?: the ten-year results of the New Zealand Joint Registry. J Bone Joint Surg Br. 2011 Jan;93(1):85-90.

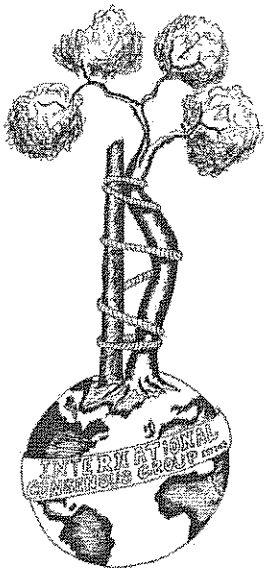
44. Merollini KMD, Crawford RW, Whitehouse SL, Graves N. Surgical site infection prevention following total hip arthroplasty in Australia: a cost-effectiveness analysis. Am J Infect Control. 2013 Sep;41(9):803-9. Epub 2013 Feb 21.

EXHIBIT DX18

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

Proceedings of the International Consensus Meeting on Periprosthetic Joint Infection

Chairmen:
Javad Parvizi MD, FRCS
Thorsten Gehrke MD



This document is an excerpt—printed with permission—from the International Consensus Meeting on Periprosthetic Joint Infection Full Report (Workgroup 4: Operative Environment, pp. 125-127).

To download the full report, visit *www.msis-na.org/international-consensus*

Foreword

"The doorstep to the temple of wisdom is a knowledge of our own ignorance."

Benjamin Franklin

The battle against infection is as old as human civilization. During the last few centuries, great scholars such as Louis Pasteur, Ignaz Philipp Semmelweis, Alexander Fleming, and Joseph Lister have transformed the practice of medicine through their extraordinary discoveries. Despite the progress made and strides gained, our mission to prevent infection following surgery remains unaccomplished. It is not an exaggeration to claim that fear of infection lives in the hearts of every surgeon who steps into the operating room daily.

Periprosthetic joint infection (PJI), with all its disastrous consequences, continues to pose a challenge to the orthopaedic community. Practicing orthopaedic surgeons have invested great efforts to implement strategies that may minimize surgical site infection (SSI). Although high level evidence may support some of these practices, many are based on little to no scientific foundation. Thus, there is a remarkable variation in practices across the globe for prevention and management of PJI.

The medical community comprehends the importance of high-level evidence and engages in the generation of such whenever possible. The community also recognizes that some aspects of medicine will never lend themselves to the generation of high-level evidence nor should one attempt to do so. It is with the recognition of the latter that The International Consensus Meeting on Periprosthetic Joint Infection was organized. Delegates from various disciplines including orthopaedic surgery, infectious disease, musculoskeletal pathology, microbiology, anesthesiology, dermatology, nuclear medicine, rheumatology, musculoskeletal radiology, veterinary surgery, pharmacy, and numerous scientists with interest in orthopaedic infections came together to evaluate the available evidence, when present, or reach consensus regarding current practices for management of SSI/PJI.

The process of generating the consensus has spanned over 10 months. Every stone has been turned in search of evidence for these questions, with over 3,500 related publications evaluated. The evidence, when available, has been assessed. Otherwise the cumulative wisdom of 400 delegates from 52 countries and over 160 societies has been amassed to reach consensus about practices that lack higher level of evidence. The leadership of the Musculoskeletal Infection Society (MSIS) and the European Bone and Joint Infection Society (EBJIS), the two societies whose mission is to improve care of patients with musculoskeletal infection, have, in particular, contributed to this initiative immensely.

The delegates have been engaged every step of the way by communicating through a "social" website generated for this purpose (www.ForMD.com), with over 25,000 communications exchanged. The consensus document has been developed using the Delphi method under the leadership of Dr. Cats-Baril, a world-renowned expert in consensus development. The design of the consensus process was to include as many stakeholders as possible, allow participation in multiple forums, and provide a comprehensive review of the literature. All relevant topics on PJI were assigned into one of 15 different workgroups as follows: mitigation and education on co-morbidities associated with increased SSI/PJI, perioperative skin preparation, perioperative antibiotics, operative environment, blood conservation, prosthesis selection, diagnosis of PJI, wound management, spacers, irrigation and debridement, antibiotic treatment and timing of reimplantation, one-stage versus two-stage exchange arthroplasty, management of fungal or atypical PJI, oral antibiotic therapy, and prevention of late PJI. Every consensus statement has undergone extreme scrutiny, especially by those with expertise in a specific area to ensure that implementation of these practices will lead to improvement of patient care.

After synthesizing the literature and assembling a preliminary draft of the consensus statement, over 300 delegates attended the face-to-face meeting in Philadelphia and were involved in active discussions and voting on the questions/consensus statements.

The delegates first met on July 31 in smaller workgroups to discuss and resolve any discrepancies and finalize their statements. Then, the delegates met in the general assembly for further discussion of questions and consensus statements. After revision, the finalized consensus statement was assembled and the document was forwarded to the Audience Response System that evening for voting to begin the next day.

On August 1, 2013 the delegates came into the general assembly and voted on the 207 questions/consensus statements that were presented. The voting process was conducted using electronic keypads, where one could agree with the consensus statement, disagree, or abstain from voting. The strength of the consensus was judged according to the following scale: 1) Simple Majority: No Consensus (50.1%-59% agreement), 2) Majority: Weak Consensus (60%-65% agreement), 3) Super Majority: Strong Consensus (66%-99% agreement), and 4) Unanimous: 100% agreement. Of the 207 questions, there was unanimous vote for one question (controlling OR traffic), 202 questions received super majority (strong consensus), two questions had weak consensus, and only two questions did not achieve any consensus.

The document presented here is the result of innumerable hours of work by the liaisons, leaders, and delegates dedicated to this historic initiative. The information conveyed in this document is based on evidence, whenever present, or is the result of the cumulative wisdom of over 400 of the world's experts in musculoskeletal infection from 52 countries. We are certain that the "best practice guide" set forth by this initiative will serve many of our patients for years to come. It is essential to state that the information contained in this document is merely a guide to practicing physicians who treat patients with musculoskeletal infection and should not be considered as a standard of care. Clinicians should exercise their wisdom and clinical acumen in making decisions related to each individual patient. In some circumstances this may require implementation of care that differs from what is stated in this document.

On with our fight against infection.

Javad Parvizi MD, FRCS

Question 15: Do FAW blankets increase the risk of SSI?

Consensus: We recognize the theoretical risk posed by FAW blankets and that no studies have shown an increase in SSI related to the use of these devices. We recommend further study but no change to current practice.

Delegate Vote: Agree: 89%, Disagree: 5%, Abstain: 6% (Strong Consensus)

Justification: Recent studies have raised concern about the possibility of bacterial air contamination by FAW devices. Some authors evaluated disruptions in airflow. McGovern et al. conducted an experimental study where they found that FAW blankets lead to a disruption in the airflow at the surgical site under LAF conditions when compared to conductive fabric warmers in simulated THA and spine surgery.[76] Legg et al. found increased air particles above the surgical site when using FAW compared to radiant warming.[77] On the contrary, Sessler et al. did not identify any worsening in air quality with use of FAW under laminar flow conditions.[78] Memarzadeh et al. reported the results of a computational study conducted by the National Institutes of Health which showed negligible disruption of laminar flow by FAW.[79]

Other authors have investigated the bacterial contamination of OR air. Moretti et al. undertook air sampling in experimental conditions and demonstrated increased bacterial contamination of air after turning FAW blankets on; however, this was much lower than worsening of air quality induced by personnel placing a patient in the OR.[80] Tumia et al. undertook air sampling under LAF conditions in orthopaedic procedures and failed to identify any significant rise in air bacterial counts with the use of FAW.[81] Sharp et al. also performed air sampling in LAF equipped ORs to study the effect of FAW on air quality using volunteer patients with psoriasis who had increased shedding of skin cells.[82] Air at 30cm from a theoretical operating site was sampled and there were no positive cultures. In addition, a smoke test that was used to visually assess airflow found no disturbance by the FAW device. Zink et al. were also concerned by possible contamination of the OR environment with FAW, but did not resort to air sampling. Instead, they placed culture plates on the abdomen of volunteers with use of FAW and failed to identify increased contamination rates with this method.[83]

Albrecht et al. found that the intake filters used in air blowers were not optimally efficient and resulted in colonization of the internal parts of the device. Overall, 92% of the devices they tested resulted in positive bacterial growth with organisms that are typically implicated in PJI (mostly Staphylococci species).[84] However, there is no concrete evidence to link the use of FAW system with SSI/PJI. McGovern et al studied a change of a warming system from forced air to an alternative system in 1,437 patients. A significant increase in deep joint infection, as demonstrated by an elevated infection odds ratio (3.8, p=0.024), was identified during a period when FAW was used compared to a period when conductive fabric warming was used. The authors conceded that the study was observational and may have been affected by other infection prevention measures instituted by the hospital.[76]

References:

76. McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. *J Bone Joint Surg Br.* 2011;93(11):1537-1544.
77. Legg AJ, Cannon T, Hamer AJ. Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone Joint Surg Br.* 2012;94(2):254-256.
78. Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. *Anesth Analg.* 2011;113(6):1416-1421.
79. Memarzadeh F. Active warming systems to maintain perioperative normothermia in hip replacement surgery. *J Hosp Infect.* 2010;75(4):332-333.
80. Moretti B, Larocca AM, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? *J Hosp Infect.* 2009;73(1):58-63.
81. Tumia N, Ashcroft GP. Convection warmers--a possible source of contamination in laminar airflow operating theatres? *J Hosp Infect.* 2002;52(3):171-174.
82. Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? *J Bone Joint Surg Br.* 2002;84(4):486-488.
83. Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. *Anesth Analg.* 1993;76(1):50-53.
84. Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: An evaluation of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control.* 2011;39(4):321-328.

EXHIBIT DX19

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

SPECIAL ARTICLES

Guideline for Prevention of Surgical Site Infection, 1999

Alicia J. Mangram, MD; Teresa C. Horan, MPH, CIC; Michele L. Pearson, MD; Leah Christine Silver, BS; William R. Jarvis, MD; The Hospital Infection Control Practices Advisory Committee

From the Hospital Infections Program
National Center for Infectious Diseases
Centers for Disease Control and Prevention
Public Health Service
U.S. Department of Health and Human Services

Hospital Infection Control Practices Advisory Committee
Membership List, January 1999

Chairman
Elaine L. Larson, RN, PhD, FAAN, CIC
Columbia University School of Nursing
New York, New York

Executive Secretary
Michele L. Pearson, MD
Centers for Disease Control and Prevention
Atlanta, Georgia

Surgical Site Infection Guideline Sponsor
James T. Lee, MD, PhD, FACS
University of Minnesota
Minneapolis, Minnesota

Members
Audrey B. Adams, RN, MPH
Montefiore Medical Center
Bronx, New York

Raymond Y. W. Chinn, MD
Sharp Memorial Hospital
San Diego, California

Alfred DeMaria, Jr, MD
Massachusetts Department of Public Health
Jamaica Plain, Massachusetts

Susan W. Forlenza, MD
New York City Health Department
New York, New York

Ramon E. Moncada, MD
Coronado Physician's Medical Center
Coronado, California

William E. Scheckler, MD
University of Wisconsin Medical School
Madison, Wisconsin

Jane D. Siegel, MD
University of Texas Southwestern Medical Center
Dallas, Texas

Marjorie A. Underwood, RN, BSN, CIC
Mt. Diablo Medical Center
Concord, California

Robert A. Weinstein, MD
Cook County Hospital
Chicago, Illinois

From the Hospital Infections Program, National Center for Infectious Diseases, Centers for Disease Control and Prevention, Public Health Service, US Department of Health and Human Services, Atlanta, Georgia.

Reprint requests: SSI Guideline, Hospital Infections Program, Mailstop E-69, Center for Disease Control and Prevention, 1600 Clifton Rd, Atlanta, GA 30333. The "Guideline for Prevention of Surgical Site Infection, 1999" is available online at *www.cdc.gov/ncidod/hip.*

Published simultaneously in *Infection Control and Hospital Epidemiology; AJIC: American Journal of Infection Control* 1999;27:97-134; and the *Journal of Surgical Outcomes.*

Dr. Mangram is currently affiliated with the University of Texas Medical Center, Houston, Texas.

17/52/98051

Table of Contents

EXECUTIVE SUMMARY

The "Guideline for Prevention of Surgical Site Infection, 1999" presents the Centers for Disease Control and Prevention (CDC)'s recommendations for the prevention of surgical site infections (SSIs), formerly called surgical wound infections. This two-part guideline updates and replaces previous guidelines.[1,2]

Part I, "Surgical Site Infection: An Overview," describes the epidemiology, definitions, microbiology, pathogenesis, and surveillance of SSIs. Included is a detailed discussion of the pre-, intra-, and postoperative issues relevant to SSI genesis.

Part II, "Recommendations for Prevention of Surgical Site Infection," represents the consensus of the Hospital Infection Control Practices Advisory Committee (HICPAC) regarding strategies for the prevention of SSIs.[3] Whenever possible, the recommendations in Part II are based on data from well-designed scientific studies. However, there are a limited number of studies that clearly validate risk factors and prevention measures for SSI. By necessity, available studies have often been conducted in narrowly defined patient populations or for specific kinds of operations, making generalization of their findings to all specialties and types of operations potentially problematic. This is especially true regarding the implementation of SSI prevention measures. Finally, some of the infection control practices routinely used by surgical teams cannot be rigorously studied for ethical or logistical reasons (e.g., wearing vs not wearing gloves). Thus, some of the recommendations in Part II are based on a strong theoretical rationale and suggestive evidence in the absence of confirmatory scientific knowledge.

It has been estimated that approximately 75% of all operations in the United States will be performed in "ambulatory," "same-day," or "outpatient" operating rooms by the turn of the century.[4] In recommending various SSI prevention methods, this document makes no distinction between surgical care delivered in such settings and that provided in conventional inpatient operating rooms. This document is primarily intended for use by surgeons, operating room nurses, postoperative inpatient and clinic nurses, infection control professionals, anesthesiologists, healthcare epidemiologists, and other personnel directly responsible for the prevention of nosocomial infections.

This document does *not:*

- Specifically address issues unique to burns, trauma, transplant procedures, or transmission of bloodborne pathogens from healthcare worker to patient, nor does it specifically address details of SSI prevention in pediatric surgical practice. It has been recently shown in a multicenter study of pediatric surgical patients that characteristics related to the operations are more important than those related to the physiologic status of the patients.[5] In general, all SSI prevention measures effective in adult surgical care are indicated in pediatric surgical care.
- Specifically address procedures performed outside of the operating room (e.g., endoscopic proce-

dures), nor does it provide guidance for infection prevention for invasive procedures such as cardiac catheterization or interventional radiology. Nonetheless, it is likely that many SSI prevention strategies also could be applied or adapted to reduce infectious complications associated with these procedures.

- Specifically recommend SSI prevention methods unique to minimally invasive operations (i.e., laparoscopic surgery). Available SSI surveillance data indicate that laparoscopic operations generally have a lower or comparable SSI risk when contrasted to open operations.[6-11] SSI prevention measures applicable in open operations (e.g., open cholecystectomy) are indicated for their laparoscopic counterparts (e.g., laparoscopic cholecystectomy).
- Recommend specific antiseptic agents for patient preoperative skin preparations or for healthcare worker hand/forearm antisepsis. Hospitals should choose from products recommended for these activities in the latest Food and Drug Administration (FDA) monograph.[12]

I. Surgical Site Infection (SSI): An Overview

A. INTRODUCTION

Before the mid-19th century, surgical patients commonly developed postoperative "irritative fever," followed by purulent drainage from their incisions, overwhelming sepsis, and often death. It was not until the late 1860s, after Joseph Lister introduced the principles of antisepsis, that postoperative infectious morbidity decreased substantially. Lister's work radically changed surgery from an activity associated with infection and death to a discipline that could eliminate suffering and prolong life.

Currently, in the United States alone, an estimated 27 million surgical procedures are performed each year.[13] The CDC's National Nosocomial Infections Surveillance (NNIS) system, established in 1970, monitors reported trends in nosocomial infections in U.S. acute-care hospitals. Based on NNIS system reports, SSIs are the third most frequently reported nosocomial infection, accounting for 14% to 16% of all nosocomial infections among hospitalized patients.[14] During 1986 to 1996, hospitals conducting SSI surveillance in the NNIS system reported 15,523 SSIs following 593,344 operations (CDC, unpublished data). Among surgical patients, SSIs were the most common nosocomial infection, accounting for 38% of all such infections. Of these SSIs, two thirds were confined to the incision, and one third involved organs or spaces accessed during the operation. When surgical patients with nosocomial SSI died, 77% of the deaths were reported to be related to the infection, and the majority (93%) were serious infections involving organs or spaces accessed during the operation.

In 1980, Cruse estimated that an SSI increased a patient's hospital stay by approximately 10 days and cost an additional $2,000.[15,16] A 1992 analysis showed that each SSI resulted in 7.3 additional postoperative hospital days, adding $3,152 in extra charges.[17] Other studies corroborate that increased length of hospital stay and cost are associated with SSIs.[18,19] Deep SSIs involving organs or spaces, as compared to SSIs confined to the incision, are associated with even greater increases in hospital stays and costs.[20,21]

Advances in infection control practices include improved operating room ventilation, sterilization methods, barriers, surgical technique, and availability of antimicrobial prophylaxis. Despite these activities, SSIs remain a substantial cause of morbidity and mortality among hospitalized patients. This may be partially explained by the emergence of antimicrobial-resistant pathogens and the increased numbers of surgical patients who are elderly and/or have a wide variety of chronic, debilitating, or immunocompromising underlying diseases. There also are increased numbers of prosthetic implant and organ transplant operations performed. Thus, to reduce the risk of SSI, a systematic but realistic approach must be applied with the awareness that this risk is influenced by characteristics of the patient, operation, personnel, and hospital.

B. KEY TERMS USED IN THE GUIDELINE

1. Criteria for defining SSIs

The identification of SSI involves interpretation of clinical and laboratory findings, and it is crucial that a surveillance program use definitions that are consistent and standardized; otherwise, inaccurate or uninterpretable SSI rates will be computed and reported. The CDC's NNIS system has developed standardized surveillance criteria for defining SSIs (Table 1).[22] By these criteria, SSIs are classified as being either incisional or organ/space. Incisional SSIs are further divided into those involving only skin and subcutaneous tissue (superficial incisional SSI) and those involving deeper soft tissues of the incision (deep incisional SSI). Organ/space SSIs involve any part of the anatomy (e.g., organ or space) other than incised body wall layers, that

Table 1. Criteria for Defining a Surgical Site Infection (SSI)*

Superficial Incisional SSI

Infection occurs within 30 days after the operation *and* infection involves only skin or subcutaneous tissue of the incision *and* at least *one* of the following:

1. Purulent drainage, with or without laboratory confirmation, from the superficial incision.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue from the superficial incision.
3. At least one of the following signs or symptoms of infection: pain or tenderness, localized swelling, redness, or heat *and* superficial incision is deliberately opened by surgeon, *unless* incision is culture-negative.
4. Diagnosis of superficial incisional SSI by the surgeon or attending physician.

Do *not* report the following conditions as SSI:

1. Stitch abscess (minimal inflammation and discharge confined to the points of suture penetration).
2. Infection of an episiotomy or newborn circumcision site.
3. Infected burn wound.
4. Incisional SSI that extends into the fascial and muscle layers (see deep incisional SSI).

Note: Specific criteria are used for identifying infected episiotomy and circumcision sites and burn wounds.[433]

Deep incisional SSI

Infection occurs within 30 days after the operation if no implant† is left in place or within 1 year if implant is in place and the infection appears to be related to the operation *and* infection involves deep soft tissues (e.g., fascial and muscle layers) of the incision *and* at least *one* of the following:

1. Purulent drainage from the deep incision but not from the organ/space component of the surgical site.
2. A deep incision spontaneously dehisces or is deliberately opened by a surgeon when the patient has at least one of the following signs or symptoms: fever (>38°C), localized pain, or tenderness, unless site is culture-negative.
3. An abscess or other evidence of infection involving the deep incision is found on direct examination, during reoperation, or by histopathologic or radiologic examination.
4. Diagnosis of a deep incisional SSI by a surgeon or attending physician.

Notes:

1. Report infection that involves both superficial and deep incision sites as deep incisional SSI.
2. Report an organ/space SSI that drains through the incision as a deep incisional SSI.

Organ/space SSI

Infection occurs within 30 days after the operation if no implant† is left in place or within 1 year if implant is in place and the infection appears to be related to the operation *and* infection involves any part of the anatomy (e.g., organs or spaces), other than the incision, which was opened or manipulated during an operation *and* at least *one* of the following:

1. Purulent drainage from a drain that is placed through a stab wound‡ into the organ/space.
2. Organisms isolated from an aseptically obtained culture of fluid or tissue in the organ/space.
3. An abscess or other evidence of infection involving the organ/space that is found on direct examination, during reoperation, or by histopathologic or radiologic examination.
4. Diagnosis of an organ/space SSI by a surgeon or attending physician.

* Horan TC et al.[22]

†National Nosocomial Infection Surveillance definition: a nonhuman-derived implantable foreign body (e.g., prosthetic heart valve, nonhuman vascular graft, mechanical heart, or hip prosthesis) that is permanently placed in a patient during surgery.

‡If the area around a stab wound becomes infected, it is not an SSI. It is considered a skin or soft tissue infection, depending on its depth.

was opened or manipulated during an operation (Figure). Table 2 lists site-specific classifications used to differentiate organ/space SSIs. For example, in a patient who had an appendectomy and subsequently developed an intra-abdominal abscess not draining through the incision, the infection would be reported as an organ/space SSI at the intra-abdominal site. Failure to use objective criteria to define SSIs has been shown to substantially affect reported SSI rates.[23,24] The CDC NNIS definitions of SSIs have been applied consistently by surveillance and surgical personnel in many settings and currently are a de facto national standard.[22,25]

2. Operating suite

A physically separate area that comprises operating rooms and their interconnecting hallways and ancillary work areas such as scrub sink rooms. No distinction is made between operating suites located in conventional inpatient hospitals and those used for "same-day" surgical care, whether in a hospital or a free-standing facility.

3. Operating room

A room in an operating suite where operations are performed.

4. Surgical personnel

Any healthcare worker who provides care to surgical patients during the pre-, intra-, or postoperative periods.

5. Surgical team member

Any healthcare worker in an operating room during the operation who has a surgical care role. Members of the surgical team may be "scrubbed" or not; scrubbed members have direct contact with the sterile operating field or

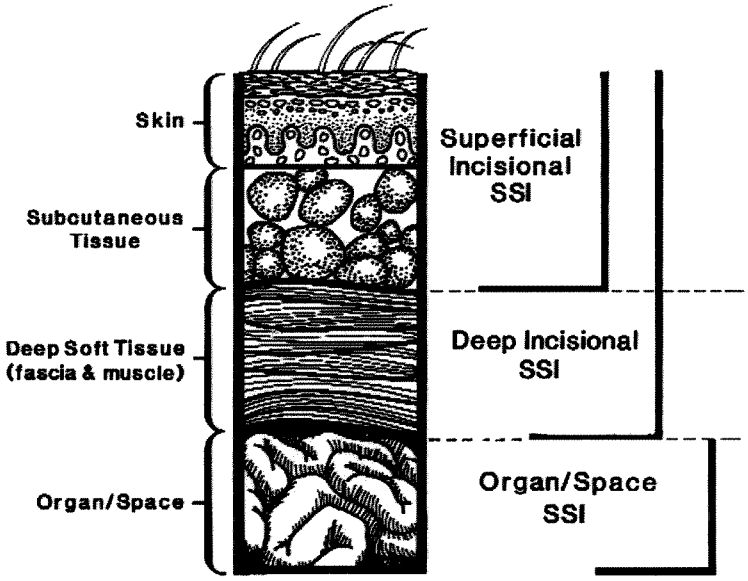


Figure. Cross-section of abdominal wall depicting CDC classifications of surgical site infection.[22]

sterile instruments or supplies used in the field (refer to "Preoperative Hand/Forearm Antisepsis" section).

C. MICROBIOLOGY

According to data from the NNIS system, the distribution of pathogens isolated from SSIs has not changed markedly during the last decade (Table 3).[26,27] *Staphylococcus aureus*, coagulase-negative staphylococci, *Enterococcus* spp., and *Escherichia coli* remain the most frequently isolated pathogens. An increasing proportion of SSIs are caused by antimicrobial-resistant pathogens, such as methicillin-resistant *S. aureus* (MRSA),[28,29] or by *Candida albicans*.[30] From 1991 to 1995, the incidence of fungal SSIs among patients at NNIS hospitals increased from 0.1 to 0.3 per 1,000 discharges.[30] The increased proportion of SSIs caused by resistant pathogens and *Candida* spp. may reflect increasing numbers of severely ill and immunocompromised surgical patients and the impact of widespread use of broad-spectrum antimicrobial agents.

Outbreaks or clusters of SSIs have also been caused by unusual pathogens, such as *Rhizopus oryzae, Clostridium perfringens, Rhodococcus bronchialis, Nocardia farcinica, Legionella pneumophila* and *Legionella dumoffii,* and *Pseudomonas multivorans.* These rare outbreaks have been traced to contaminated adhesive dressings,[31] elastic bandages,[32] colonized surgical personnel,[33,34] tap water,[35] or contaminated disinfectant solutions.[36] When a cluster of SSIs involves an unusual organism, a formal epidemiologic investigation should be conducted.

D. PATHOGENESIS

Microbial contamination of the surgical site is a necessary precursor of SSI. The risk of SSI can be conceptualized according to the following relationship[37,38]:

$$\frac{\text{Dose of bacterial contamination} \times \text{virulence}}{\text{Resistance of the host patient}} = \text{Risk of surgical site infection}$$

Quantitatively, it has been shown that if a surgical site is contaminated with $>10^5$ microorganisms per gram of tissue, the risk of SSI is markedly increased.[39] However, the dose of contaminating microorganisms required to produce infection may be much lower when foreign material is present at the site (i.e., 100 staphylococci per gram of tissue introduced on silk sutures).[40-42]

Microorganisms may contain or produce toxins and other substances that increase their ability to invade a host, produce damage within the host, or survive on or in host tissue. For example, many gram-negative bacteria produce endotoxin, which stimulates cytokine production. In turn, cytokines can trigger the systemic inflammatory response syndrome that sometimes leads to multiple system organ failure.[43-45] One of the most common causes of multiple system organ failure in modern surgical care is intra-abdominal infection.[46,47] Some bacterial surface components, notably polysaccharide capsules, inhibit phagocytosis,[48] a critical and early host defense response to microbial contamination. Certain strains of clostridia and streptococci produce potent exotoxins that disrupt cell membranes or alter cellular metabolism.[49] A variety of microorgan-

Table 2. Site-Specific Classifications of Organ/Space Surgical Site Infection*

Arterial or venous infection	Meningitis or ventriculitis
Breast abscess or mastitis	Myocarditis or pericarditis
Disc space	Oral cavity (mouth, tongue, or gums)
Ear, mastoid	Osteomyelitis
Endocarditis	Other infections of the lower respiratory tract (e.g., abscess or empyema)
Endometritis	Other male or female reproductive tract
Eye, other than conjunctivitis	Sinusitis
Gastrointestinal tract	Spinal abscess without meningitis
Intra-abdominal, not specified elsewhere	Upper respiratory tract
Intracranial, brain abscess or dura	Vaginal cuff
Joint or bursa	
Mediastinitis	

*Horan TC et al.[22]

Table 3. Distribution of Pathogens Isolated* From Surgical Site Infections, National Nosocomial Infections Surveillance System, 1986 to 1996

	Percentage of isolates	
Pathogen	**1986-1989[179] (N=16,727)**	**1990-1996[26] (N=17,671)**
Staphylococcus aureus	17	20
Coagulase-negative staphylococci	12	14
Enterococcus spp.	13	12
Escherichia coli	10	8
Pseudomonas aeruginosa	8	8
Enterobacter spp.	8	7
Proteus mirabilis	4	3
Klebsiella pneumoniae	3	3
Other *Streptococcus* spp.	3	3
Candida albicans	2	3
Group D streptococci (non-enterococci)	—	2
Other gram-positive aerobes	—	2
Bacteroides fragilis	—	2

*Pathogens representing less than 2% of isolates are excluded.

isms, including gram-positive bacteria such as coagulase-negative staphylococci, produce glycocalyx and an associated component called "slime,"[50-55] which physically shields bacteria from phagocytes or inhibits the binding or penetration of antimicrobial agents.[56] Although these and other virulence factors are well defined, their mechanistic relationship to SSI development has not been fully determined.

For most SSIs, the source of pathogens is the endogenous flora of the patient's skin, mucous membranes, or hollow viscera.[57] When mucous membranes or skin is incised, the exposed tissues are at risk for contamination with endogenous flora.[58] These organisms are usually aerobic gram-positive cocci (e.g., staphylococci), but may include fecal flora (e.g., anaerobic bacteria and gram-negative aerobes) when incisions are made near the perineum or groin. When a gastrointestinal organ is opened during an operation and is the source of pathogens, gram-negative bacilli (e.g., *E. coli*), gram-positive organisms (e.g., enterococci), and sometimes anaerobes (e.g., *Bacillus fragilis*) are the typical SSI isolates. Table 4 lists operations and the likely SSI pathogens associated with them. Seeding of the operative site from a distant focus of infection can be another source of SSI pathogens,[59-68] particularly in patients who have a prosthesis or other implant placed during the operation. Such devices provide a nidus for attachment of the organism.[50,69-73]

Exogenous sources of SSI pathogens include surgical personnel (especially members of the surgical team),[74-78] the operating room environment (including air), and all tools, instruments, and materials brought to the sterile field during an operation (refer to "Intraoperative Issues" section). Exogenous flora are primarily aerobes, especially gram-positive organisms (e.g., staphylococci and streptococci). Fungi from endogenous and exogenous sources rarely cause SSIs, and their pathogenesis is not well understood.[79]

E. RISK AND PREVENTION

The term *risk factor* has a particular meaning in epidemiology and, in the context of SSI pathophysiol-

Table 4. Operations, Likely Surgical Site Infection (SSI) Pathogens, and References on Usage of Antimicrobial Prophylaxis*

Operations	Likely Pathogens†‡	References
Placement of all grafts, prostheses, or implants	*Staphylococcus aureus*; coagulase-negative staphylococci	269,282-284,290
Cardiac	*Staphylococcus aureus*; coagulase-negative staphylococci	251-253,462,463
Neurosurgery	*Staphylococcus aureus*; coagulase-negative staphylococci	241,249,258,259,261, 464,465
Breast	*Staphylococcus aureus;* coagulase-negative staphylococci	242,248
Ophthalmic Limited data: however, commonly used in procedures such as anterior segment resection, vitrectomy, and scleral buckles	*Staphylococcus aureus*; coagulase-negative staphylococci; streptococci; gram-negative bacilli	466
Orthopedic Total joint replacement Closed fractures/use of nails, bone plates, other internal fixation devices Functional repair without implant/device Trauma	*Staphylococcus aureus;* coagulase-negative staphylococci; gram-negative bacilli	60,243-246,254, 255,467-473
Noncardiac thoracic Thoracic (lobectomy, pneumonectomy, wedge resection, other noncardiac mediastinal procedures) Closed tube thoracostomy	*Staphylococcus aureus;* coagulase-negative staphylococci; *Streptococcus pneumoniae;* gram-negative bacilli	240,247,474,475
Vascular	*Staphylococcus aureus;* coagulase-negative staphylococci	250,463,476,477
Appendectomy	Gram-negative bacilli; anaerobes	263,452,478
Biliary tract	Gram-negative bacilli; anaerobes	260,262,479-484
Colorectal	Gram-negative bacilli; anaerobes	200,239,256,287 289,485-490
Gastroduodenal	Gram-negative bacilli; streptococci; oropharyngeal anaerobes (e.g., peptostreptococci)	256,257,491-493
Head and neck (major procedures with incision through oropharyngeal mucosa)	*Staphylococcus aureus*; streptococci; oropharyngeal anaerobes (e.g., peptostreptococci)	494-497
Obstetric and gynecologic	Gram-negative bacilli; enterococci; group B streptococci; anaerobes	270-280,435
Urologic May not be beneficial if urine is sterile	Gram-negative bacilli	267

*Refer to "Antimicrobial prophylaxis in surgery," The Medical Letter, 1997,[266] for current recommendations of antimicrobial agents and doses.
†Likely pathogens from both endogenous and exogenous sources.
‡Staphylococci will be associated with SSI following all types of operations.

ogy and prevention, strictly refers to a variable that has a significant, independent association with the development of SSI after a specific operation. Risk factors are identified by multivariate analyses in epidemiologic studies. Unfortunately, the term risk factor often is used in the surgical literature in a broad sense to include patient or operation features which, although associated with SSI development in univariate analysis, are not necessarily independent predictors.[80] The literature cited in the sections that follow includes risk factors identified by both univariate and multivariate analyses.

Table 5 lists patient and operation characteristics that may influence the risk of SSI development. These characteristics are useful in two ways: (1) they allow stratification of operations, making surveillance data more comprehensible; and, (2) knowledge of risk factors before certain operations may allow for targeted prevention measures. For example, if it is known that a patient has a remote site infection, the surgical team may reduce SSI risk by scheduling an operation after the infection has resolved.

An SSI prevention measure can be defined as an action or set of actions intentionally taken to reduce the risk of an SSI. Many such techniques are directed at reducing opportunities for microbial contamination of the patient's tissues or sterile surgical instruments; others are adjunctive, such as using antimicrobial prophylaxis or avoiding unnecessary traumatic tissue dissection. Optimum application of SSI prevention measures requires that a variety of patient and operation characteristics be carefully considered.

1. Patient characteristics

In certain kinds of operations, patient characteristics possibly associated with an increased risk of an SSI include coincident remote site infections [59-68] or colonization,[81-83] diabetes,[84-87] cigarette smoking,[85,88-92] systemic steroid use,[84,87,93] obesity (>20% ideal body weight),[85-87,94-97] extremes of age,[92,98-102] poor nutritional status,[85,94,98,103-105] and perioperative transfusion of certain blood products.[106-109]

a. Diabetes

The contribution of diabetes to SSI risk is controversial,[84-86,98,110] because the independent contribution of diabetes to SSI risk has not typically been assessed after controlling for potential confounding factors. Recent preliminary findings from a study of patients who underwent coronary artery bypass graft showed a significant relationship between increasing levels of HgA1c and SSI rates.[111] Also, increased glucose levels (>200 mg/dL) in the immediate postoperative period (≤48 hours) were associated with increased SSI risk.[112,113] More studies are needed to assess the efficacy of perioperative blood glucose control as a prevention measure.

b. Nicotine use

Nicotine use delays primary wound healing and may increase the risk of SSI.[85] In a large prospective study, current cigarette smoking was an independent risk factor for sternal and/or mediastinal SSI following cardiac surgery.[85] Other studies have corroborated cigarette smoking as an important SSI risk factor.[88-92] The limitation of these studies, however, is that terms like *current cigarette smoking* and *active smokers* are not always defined. To appropriately determine the contribution of tobacco use to SSI risk, standardized definitions of smoking history must be adopted and used in studies designed to control for confounding variables.

c. Steroid use

Patients who are receiving steroids or other immunosuppressive drugs preoperatively may be predisposed to developing SSI,[84,87] but the data supporting this relationship are contradictory. In a study of long-term steroid use in patients with Crohn's disease, SSI developed significantly more often in patients receiving preoperative steroids (12.5%) than in patients without steroid use (6.7%).[93] In contrast, other investigations have not found a relationship between steroid use and SSI risk.[98,114,115]

d. Malnutrition

For some types of operations, severe protein-calorie malnutrition is crudely associated with postoperative nosocomial infections, impaired wound healing dynamics, or death.[116-124] The National Academy of Sciences/National Research Council (NAS/NRC),[94] Study on the Efficacy of Infection Control (SENIC),[125] and NNIS[126] schemes for SSI risk stratification do not explicitly incorporate nutritional status as a predictor variable, although it may be represented indirectly in the latter two. In a widely quoted 1987 study of 404 high-risk general surgery operations, Christou and coworkers derived an SSI probability index in which final predictor variables were patient age, operation duration, serum albumin level, delayed hypersensitivity test score, and intrinsic wound contamination level.[117] Although this index predicted SSI risk satisfactorily for 404 subsequent patients and was generally received as a significant advance in SSI risk stratification, it is not widely used in SSI surveillance data analysis, surgical infection research, or analytic epidemiology.

Theoretical arguments can be made for a belief that severe preoperative malnutrition should increase the risk of both incisional and organ/space SSI. However, an epidemiologic association between incisional SSI and malnutrition is difficult to demonstrate consistently for all surgical subspecialties.[118-120,124,127-131] Multivariate logistic regression modeling has shown that preoperative protein-calorie malnutrition is not an independent predictor of mediastinitis after cardiac bypass operations.[85,132]

In the modern era, total parenteral nutrition (TPN) and total enteral alimentation (TEA) have enthusiastic acceptance by surgeons and critical care specialists.[118,133-137] However, the benefits of preoperative nutritional repletion of malnourished patients in reducing

Table 5. Patient and Operation Characteristics That May Influence the Risk of Surgical Site Infection Development

Patient
Age
Nutritional status
Diabetes
Smoking
Obesity
Coexistent infections at a remote body site
Colonization with microorganisms
Altered immune response
Length of preoperative stay
Operation
Duration of surgical scrub
Skin antisepsis
Preoperative shaving
Preoperative skin prep
Duration of operation
Antimicrobial prophylaxis
Operating room ventilation
Inadequate sterilization of instruments
Foreign material in the surgical site
Surgical drains
Surgical technique
Poor hemostasis
Failure to obliterate dead space
Tissue trauma

Adapted from references 25, 37.

SSI risk are unproven. In two randomized clinical trials, preoperative "nutritional therapy" did not reduce incisional and organ/space SSI risk.[138-141] In a recent study of high-risk pancreatectomy patients with cancer, the provision of TPN preoperatively had no beneficial effect on SSI risk.[142] A randomized prospective trial involving 395 general and thoracic surgery patients compared outcomes for malnourished patients preoperatively receiving either a 7- to 15-day TPN regimen or a regular preoperative hospital diet. All patients were followed for 90 days postoperatively. There was no detectable benefit of TPN administration on the incidence of incisional or organ/space SSI.[143] Administering TPN or TEA may be indicated in a number of circumstances, but such repletion cannot be viewed narrowly as a prevention measure for organ/space or incisional SSI risk. When a major elective operation is necessary in a severely malnourished patient, experienced surgeons often use both pre- and postoperative nutritional support in consideration of the major morbidity associated with numerous potential complications, only one of which is organ/space SSI.[118,124,130,133,137,138,144-149] In addition, postoperative nutritional support is important for certain major oncologic operations,[135,136] after many operations on major trauma victims,[134] or in patients suffering a variety of catastrophic surgical complications that preclude eating or that trigger a hypermetabolic state. Randomized clinical trials will be necessary to determine if nutritional support alters SSI risk in specific patient-operation combinations.

e. Prolonged preoperative hospital stay

Prolonged preoperative hospital stay is frequently suggested as a patient characteristic associated with increased SSI risk. However, length of preoperative stay is likely a surrogate for severity of illness and co-morbid conditions requiring inpatient work-up and/or therapy before the operation.[16,26,65,85,94,100,150,151]

f. Preoperative nares colonization with *Staphylococcus aureus*

S. aureus is a frequent SSI isolate. This pathogen is carried in the nares of 20% to 30% of healthy humans.[81] It has been known for years that the development of SSI involving *S. aureus* is definitely associated with preoperative nares carriage of the organism in surgical patients.[81] A recent multivariate analysis demonstrated that such carriage was the most powerful independent risk factor for SSI following cardiothoracic operations.[82]

Mupirocin ointment is effective as a topical agent for eradicating *S. aureus* from the nares of colonized patients or healthcare workers. A recent report by Kluytmans and coworkers suggested that SSI risk was reduced in patients who had cardiothoracic operations when mupirocin was applied preoperatively to their nares, regardless of carrier status.[152] In this study, SSI rates for 752 mupirocin-treated patients were compared with those previously observed for an untreated group of 928 historical control patients, and the significant SSI rate reduction was attributed to the mupirocin treatment. Concerns have been raised regarding the comparability of the two patient groups.[153] Additionally, there is concern that mupirocin resistance may emerge, although this seems unlikely when treatment courses are brief.[81] A prospective, randomized clinical trial will be necessary to establish definitively that eradication of nasal carriage of *S. aureus* is an effective SSI prevention method in cardiac surgery. Such a trial has recently been completed on 3,909 patients in Iowa.[83] Five types of operations in two facilities were observed. Preliminary analysis showed a significant association between nasal carriage of *S. aureus* and subsequent SSI development. The effect of mupirocin on reducing SSI risk is yet to be determined.

g. Perioperative transfusion

It has been reported that perioperative transfusion of leukocyte-containing allogeneic blood components is an apparent risk factor for the development of postoperative bacterial infections, including SSI.[106] In three of five randomized trials conducted in patients undergoing elective colon resection for cancer, the risk of SSI was at least doubled in patients receiving blood transfusions.[107-109] However, on the basis of detailed epidemiologic reconsiderations, as many as 12 confounding variables may have influenced the reported association, and any effect of transfusion on SSI risk may be either small or nonexistent.[106] Because of methodologic problems, including the timing of transfusion, and use of nonstandardized SSI definitions, interpretation of the available data is limited. A meta-analysis of published trials will probably be required for resolution of the controversy.[154] There is currently no scientific basis for withholding necessary blood products from surgical patients as a means of either incisional or organ/space SSI risk reduction.

2. Operative characteristics: Preoperative issues

a. Preoperative antiseptic showering

A preoperative antiseptic shower or bath decreases skin microbial colony counts. In a study of >700 patients who received two preoperative antiseptic showers, chlorhexidine reduced bacterial colony counts ninefold (2.8×10^2 to 0.3), while povidone-iodine or triclocarban-medicated soap reduced colony counts by 1.3- and 1.9-fold, respectively.[155] Other studies corroborate these findings.[156,157] Chlorhexidine gluconate-containing products require several applications to attain maximum antimicrobial benefit, so repeated antiseptic showers are usually indicated.[158] Even though preoperative showers reduce the skin's microbial colony counts, they have not definitively been shown to reduce SSI rates.[159-165]

Table 6. Mechanism and Spectrum of Activity of Antiseptic Agents Commonly Used for Preoperative Skin Preparation and Surgical Scrubs

Agent	Mechanism of Action	Gram-Positive Bacteria	Gram-Negative Bacteria	Mtb	Fungi	Virus	Rapidity of Action	Residual Activity	Toxicity	Uses
Alcohol	Denature proteins	E	E	G	G	G	Most rapid	None	Drying, volatile	SP, SS
Chlorhexidine	Disrupt cell membrane	E	G	P	F	G	Intermediate	E	Ototoxicity, keratitis	SP, SS
Iodine/ Iodophors	Oxidation/ substitution by free iodine	E	G	G	G	G	Intermediate	Minimal	Absorption from skin with possible toxicity, skin irritation	SP, SS
PCMX	Disrupt cell wall	G	F*	F	F	F	Intermediate	Good	More data needed	SS
Triclosan	Disrupt cell wall	G	G	G	P	U	Intermediate	E	More data needed	SS

Abbreviations: E, excellent; F, fair; G, good; Mtb, Mycobacterium tuberculosis; P, poor; PCMX, para-chloro-meta-xylenol; SP, skin preparation; SS, surgical scrubs; U, unknown.
Data from Larson E.[176]
*Fair, except for *Pseudomonas* spp.; activity improved by addition of chelating agent such as EDTA.

b. Preoperative hair removal

Preoperative shaving of the surgical site the night before an operation is associated with a significantly higher SSI risk than either the use of depilatory agents or no hair removal.[16,100,166-169] In one study, SSI rates were 5.6% in patients who had hair removed by razor shave compared to a 0.6% rate among those who had hair removed by depilatory or who had no hair removed.[166] The increased SSI risk associated with shaving has been attributed to microscopic cuts in the skin that later serve as foci for bacterial multiplication. Shaving immediately before the operation compared to shaving within 24 hours preoperatively was associated with decreased SSI rates (3.1% vs 7.1%); if shaving was performed >24 hours prior to operation, the SSI rate exceeded 20%.[166] Clipping hair immediately before an operation also has been associated with a lower risk of SSI than shaving or clipping the night before an operation (SSI rates immediately before = 1.8% vs night before = 4.0%).[170-173] Although the use of depilatories has been associated with a lower SSI risk than shaving or clipping,[166,167] depilatories sometimes produce hypersensitivity reactions.[166] Other studies showed that preoperative hair removal by any means was associated with increased SSI rates and suggested that no hair be removed.[100,174,175]

c. Patient skin preparation in the operating room

Several antiseptic agents are available for preoperative preparation of skin at the incision site (Table 6). The iodophors (e.g., povidone-iodine), alcohol-containing products, and chlorhexidine gluconate are the most commonly used agents. No studies have adequately assessed the comparative effects of these preoperative skin antiseptics on SSI risk in well-controlled, operation-specific studies.

Alcohol is defined by the FDA as having one of the following active ingredients: ethyl alcohol, 60% to 95% by volume in an aqueous solution, or isopropyl alcohol, 50% to 91.3% by volume in an aqueous solution.[12] Alcohol is readily available, inexpensive, and remains the most effective and rapid-acting skin antiseptic.[176] Aqueous 70% to 92% alcohol solutions have germicidal activity against bacteria, fungi, and viruses, but spores can be resistant.[176,177] One potential disadvantage of the use of alcohol in the operating room is its flammability.[176-178]

Both chlorhexidine gluconate and iodophors have broad spectra of antimicrobial activity.[177,179-181] In some comparisons of the two antiseptics when used as preoperative hand scrubs, chlorhexidine gluconate achieved greater reductions in skin microflora than did povidone-iodine and also had greater residual activity after a single application.[182-184] Further, chlorhexidine gluconate is not inactivated by blood or serum proteins.[176,179,185,186] Iodophors may be inactivated by blood or serum proteins, but exert a bacteriostatic effect as long as they are present on the skin.[178,179]

Before the skin preparation of a patient is initiated, the skin should be free of gross contamination (i.e., dirt, soil, or any other debris).[187] The patient's skin is prepared by applying an antiseptic in concentric circles, beginning in the area of the proposed incision. The prepared area should be large enough to extend the incision or create new incisions or drain sites, if necessary.[1,177,187] The application of the skin preparation may need to be modified, depending on the condition of the skin (e.g., burns) or location of the incision site (e.g., face).

There are reports of modifications to the procedure for preoperative skin preparation which include: (1) removing or wiping off the skin preparation antiseptic agent after application, (2) using an antiseptic-impregnated adhesive drape, (3) merely painting the skin with an antiseptic in lieu of the skin preparation procedure described above, or (4) using a "clean" versus a "sterile" surgical skin preparation kit.[188-191] However, none of these modifications has been shown to represent an advantage.

d. Preoperative hand/forearm antisepsis

Members of the surgical team who have direct contact with the sterile operating field or sterile instruments or supplies used in the field wash their hands and forearms by performing a traditional procedure known as scrubbing (or the surgical scrub) immediately before donning sterile gowns and gloves. Ideally, the optimum antiseptic used for the scrub should have a broad spectrum of activity, be fast-acting, and have a persistent effect.[1,192,193] Antiseptic agents commercially available in the United States for this purpose contain alcohol, chlorhexidine, iodine/iodophors, para-chloro-meta-xylenol, or triclosan (Table 6).[176,177,179,194,195] Alcohol is considered the gold standard for surgical hand preparation in several European countries.[196-199] Alcohol-containing products are used less frequently in the United States than in Europe, possibly because of concerns about flammability and skin irritation. Povidone-iodine and chlorhexidine gluconate are the current agents of choice for most U.S. surgical team members.[177] However, when 7.5% povidone-iodine or 4% chlorhexidine gluconate was compared to alcoholic chlorhexidine (60% isopropanol and 0.5% chlorhexidine gluconate in 70% isopropanol), alcoholic chlorhexidine was found to have greater residual antimicrobial activity.[200,201] No agent is ideal for every situation, and a major factor, aside from the efficacy of any product, is its acceptability by operating room personnel after repeated use. Unfortunately, most studies evaluating surgical scrub antiseptics have focused on measuring hand bacterial colony counts. No clinical trials have evaluated the impact of scrub agent choice on SSI risk.[195,202-206]

Factors other than the choice of antiseptic agent influence the effectiveness of the surgical scrub. Scrubbing technique, the duration of the scrub, the condition of the hands, or the techniques used for drying and gloving are examples of such factors. Recent studies suggest that scrubbing for at least 2 minutes is as effective as the traditional 10-minute scrub in reducing hand bacterial colony counts,[207-211] but the optimum duration of scrubbing is not known. The first scrub of the day should include a thorough cleaning underneath fingernails (usually with a brush).[180,194,212] It is not clear that such cleaning is a necessary part of subsequent scrubs during the day. After performing the surgical scrub, hands should be kept up and away from the body (elbows in flexed position) so that water runs from the tips of the fingers toward the elbows. Sterile towels should be used for drying the hands and forearms before the donning of a sterile gown and gloves.[212]

A surgical team member who wears artificial nails may have increased bacterial and fungal colonization of the hands despite performing an adequate hand scrub.[212,213] Hand carriage of gram-negative organisms has been shown to be greater among wearers of artificial nails than among non-wearers.[213] An outbreak of *Serratia marcescens* SSIs in cardiovascular surgery patients was found to be associated with a surgical nurse who wore artificial nails.[214] While the relationship between nail length and SSI risk is unknown, long nails—artificial or natural—may be associated with tears in surgical gloves.[177,180,212] The relationship between the wearing of nail polish or jewelry by surgical team members and SSI risk has not been adequately studied.[194,212,215-217]

e. Management of infected or colonized surgical personnel

Surgical personnel who have active infections or are colonized with certain microorganisms have been linked to outbreaks or clusters of SSIs.[33,34,76,218-237] Thus, it is important that healthcare organizations implement policies to prevent transmission of microorganisms from personnel to patients. These policies should address management of job-related illnesses, provision of postexposure prophylaxis after job-related exposures and, when necessary, exclusion of ill personnel from work or patient contact. While work exclusion policies should be enforceable and include a statement of authority to exclude ill personnel, they should also be designed to encourage personnel to report their illnesses and exposures and not penalize personnel with loss of wages, benefits, or job status.[238]

f. Antimicrobial prophylaxis

Surgical antimicrobial prophylaxis (AMP) refers to a very brief course of an antimicrobial agent initiated just before an operation begins.[239-265] AMP is not an attempt to sterilize tissues, but a critically timed adjunct used to reduce the microbial burden of intraoperative contamination to a level that cannot overwhelm host defenses. AMP does not pertain to prevention of SSI caused by postoperative contamination.[265] Intravenous infusion is the mode of AMP delivery used most often in modern surgical practice.[20,26,242,266-281] Essentially all confirmed AMP indications pertain to elective operations in which skin incisions are closed in the operating room.

Four principles must be followed to maximize the benefits of AMP:

- Use an AMP agent for all operations or classes of operations in which its use has been shown to reduce SSI rates based on evidence from clinical trials or for those operations after which incisional or organ/space SSI would represent a catastrophe.[266,268,269,282-284]
- Use an AMP agent that is safe, inexpensive, and bactericidal with an in vitro spectrum that covers the most probable intraoperative contaminants for the operation.
- Time the infusion of the initial dose of antimicrobial agent so that a bactericidal concentration of the drug is established in serum and tissues by the time the skin is incised.[285]
- Maintain therapeutic levels of the antimicrobial agent in both serum and tissues throughout the operation and until, at most, a few hours after the incision is closed in the operating room.[179,266-268,282,284,286] Because clotted blood is present in all surgical wounds, therapeutic serum levels of AMP agents are logically important in addition to therapeutic tissue levels. Fibrin-enmeshed bacteria may be resistant to phagocytosis or to contact with antimicrobial agents that diffuse from the wound space.

Table 4 summarizes typical SSI pathogens according to operation type and cites studies that establish AMP efficacy for these operations. A simple way to organize AMP indications is based on using the surgical wound classification scheme shown in Table 7, which employs descriptive case features to *postoperatively* grade the degree of intraoperative microbial contamination. A surgeon makes the decision to use AMP by anticipating *preoperatively* the surgical wound class for a given operation.

AMP is indicated for all operations that entail entry into a hollow viscus under controlled conditions. The most frequent SSI pathogens for such clean-contaminated operations are listed in Table 4. Certain clean-contaminated operations, such as elective colon resection, low anterior resection of the rectum, and abdominoperineal resection of the rectum, also require an additional preoperative protective maneuver called "preparation of the colon," to empty the bowel of its contents and to reduce the levels of live microorganisms.[200,239,256,268,284,287] This maneuver includes the administration of enemas and cathartic agents followed by the oral administration of nonabsorbable antimicrobial agents in divided doses the day before the operation.[200,288,289]

AMP is sometimes indicated for operations that entail incisions through normal tissue and in which no viscus is entered and no inflammation or infection is encountered. Two well-recognized AMP indications for such clean operations are: (1) when any intravascular prosthetic material or a prosthetic joint will be inserted, and (2) for any operation in which an incisional or organ/space SSI would pose catastrophic risk. Examples are all cardiac operations, including cardiac pacemaker placement,[290] vascular operations involving prosthetic arterial graft placement at any site or the revascularization of the lower extremity, and most neurosurgical operations (Table 4). Some have advocated use of AMP during all operations on the breast.[80,242,264]

By definition, AMP is not indicated for an operation classified in Table 7 as contaminated or dirty. In such operations, patients are frequently receiving therapeutic antimicrobial agents perioperatively for established infections.

Cephalosporins are the most thoroughly studied AMP agents.[284] These drugs are effective against many gram-positive and gram-negative microorganisms. They also share the features of demonstrated safety, acceptable pharmacokinetics, and a reasonable cost per dose.[242] In particular, cefazolin is widely used and generally viewed as the AMP agent of first choice for clean operations.[266] If a patient is unable to receive a cephalosporin because of penicillin allergy, an alternative for gram-positive bacterial coverage is either clindamycin or vancomycin.

Cefazolin provides adequate coverage for many clean-contaminated operations,[268,291] but AMP for operations on the distal intestinal tract mandates use of an agent such as cefoxitin (or some other second-genera-

Table 7. Surgical Wound Classification

Class I/Clean: An uninfected operative wound in which no inflammation is encountered and the respiratory, alimentary, genital, or uninfected urinary tract is not entered. In addition, clean wounds are primarily closed and, if necessary, drained with closed drainage. Operative incisional wounds that follow nonpenetrating (blunt) trauma should be included in this category if they meet the criteria.
Class II/Clean-Contaminated: An operative wound in which the respiratory, alimentary, genital, or urinary tracts are entered under controlled conditions and without unusual contamination. Specifically, operations involving the biliary tract, appendix, vagina, and oropharynx are included in this category, provided no evidence of infection or major break in technique is encountered.
Class III/Contaminated: Open, fresh, accidental wounds. In addition, operations with major breaks in sterile technique (e.g., open cardiac massage) or gross spillage from the gastrointestinal tract, and incisions in which acute, nonpurulent inflammation is encountered are included in this category.
Class IV/Dirty-Infected: Old traumatic wounds with retained devitalized tissue and those that involve existing clinical infection or perforated viscera. This definition suggests that the organisms causing postoperative infection were present in the operative field before the operation.

Garner JS[1] and Simmons BP.[2]

tion cephalosporin) that provides anaerobic coverage. If a patient cannot safely receive a cephalosporin because of allergy, a reasonable alternative for gram-negative coverage is aztreonam. However, an agent such as clindamycin or metronidazole should also be included to ensure anaerobic coverage.

The aminoglycosides are seldom recommended as first choices for AMP, either as single drugs or as components of combination regimens.[242,264] References cited in Table 4 provide many details regarding AMP choices and dosages, antimicrobial spectra and properties, and other practical clinical information.

The routine use of vancomycin in AMP is not recommended for any kind of operation.[242,266,283,292] However, vancomycin may be the AMP agent of choice in certain clinical circumstances, such as when a cluster of MRSA mediastinitis or incisional SSI due to methicillin-resistant coagulase-negative staphylococci has been detected. A threshold has not been scientifically defined that can support the decision to use vancomycin in AMP. The decision should involve consideration of local frequencies of MRSA isolates, SSI rates for particular operations, review of infection prevention practices for compliance, and consultation between surgeons and infectious disease experts. An effective SSI surveillance program must be operational, with careful and timely culturing of SSI isolates to determine species and AMP agent susceptibilities.[80]

Agents most commonly used for AMP (i.e., cephalosporins) exhibit time-dependent bactericidal action. The therapeutic effects of such agents are probably maximized when their levels continuously exceed a threshold value best approximated by the minimal bactericidal concentration value observed for the target pathogens in vitro. When the duration of an operation is expected to exceed the time in which therapeutic levels of the AMP agent can be maintained, additional AMP agent should be infused. That time point for cefazolin is estimated as 3 to 4 hours. In general, the timing of a second (or third, etc.) dose of any AMP drug is estimated from three parameters: tissue levels achieved in normal patients by a standard therapeutic dose, the approximate serum half-life of the drug, and awareness of approximate MIC_{90} values for anticipated SSI pathogens. References in Table 6 should be consulted for these details and important properties of antimicrobial agents used for AMP in various specialties.

Basic "rules of thumb" guide decisions about AMP dose sizes and timing. For example, it is believed that a full therapeutic dose of cefazolin (1-2 g) should be given to adult patients no more than 30 minutes before the skin is incised.[242,285] There are a few exceptions to this basic guide. With respect to dosing, it has been demonstrated that larger doses of AMP agents are necessary to achieve optimum effect in morbidly obese patients.[293] With respect to timing, an exception occurs for patients undergoing cesarean section in whom AMP is indicated: the initial dose is administered immediately after the umbilical cord is clamped.[266,272,273] If vancomycin is used, an infusion period of approximately 1 hour is required for a typical dose. Clearly, the concept of "on-call" infusion of AMP is flawed simply because delays in transport or schedule changes can mean that suboptimal tissue and serum levels may be present when the operation starts.[242,294] Simple protocols of AMP timing and oversight responsibility should be locally designed to be practical and effective.

3. Operative characteristics: Intraoperative issues

a. Operating room environment

(1) Ventilation

Operating room air may contain microbial-laden dust, lint, skin squames, or respiratory droplets. The microbial level in operating room air is directly proportional to the number of people moving about in the room.[295] Therefore, efforts should be made to minimize personnel traffic during operations. Outbreaks of SSIs caused by group A beta-hemolytic streptococci have been traced to airborne transmission of the organism from colonized operating room personnel to patients.[233,237,296,297] In these outbreaks, the strain causing the outbreak was recovered from the air in the operating room.[237,296] It has been demonstrated that exercising and changing of clothing can lead to airborne dissemination of group A streptococci from vaginal or rectal carriage.[233,234,237,297]

Operating rooms should be maintained at positive pressure with respect to corridors and adjacent areas.[298] Positive pressure prevents airflow from less clean areas into more clean areas. All ventilation or air conditioning systems in hospitals, including those in operating rooms, should have two filter beds in series, with the efficiency of the first filter bed being ≥30% and that of the second filter bed being ≥90%.[299] Conventional operating room ventilation systems produce a minimum of about 15 air changes of filtered air per hour, three (20%) of which must be fresh air.[299,300] Air should be introduced at the ceiling and exhausted near the floor.[300,301] Detailed ventilation parameters for operating rooms have been published by the American Institute of Architects in collaboration with the U.S. Department of Health and Human Services (Table 8).[299]

Laminar airflow and use of UV radiation have been suggested as additional measures to reduce SSI risk for certain operations. Laminar airflow is designed to move particle-free air (called "ultraclean air") over the aseptic operating field at a uniform velocity (0.3 to 0.5 μm/sec),

sweeping away particles in its path. Laminar airflow can be directed vertically or horizontally, and recirculated air is usually passed through a high efficiency particulate air (HEPA) filter.[302,303] HEPA filters remove particles ≥0.3μm in diameter with an efficiency of 99.97%.[64,300,302,304] Most of the studies examining the efficacy of ultraclean air involve only orthopedic operations.[298,305-311] Charnley and Eftaknan studied vertical laminar airflow systems and exhaust-ventilated clothing and found that their use decreased the SSI rate from 9% to 1%.[305] However, other variables (i.e., surgeon experience and surgical technique) changed at the same time as the type of ventilation, which may have confounded the associations. In a multicenter study examining 8,000 total hip and knee replacements, Lidwell et al. compared the effects of ultraclean air alone, antimicrobial prophylaxis alone, and ultraclean air in combination with antimicrobial prophylaxis on the rate of deep SSIs.[307] The SSI rate following operations in which ultraclean air alone was used decreased from 3.4% to 1.6%, whereas the rate for those who received only antimicrobial prophylaxis decreased from 3.4% to 0.8%. When both interventions were used in combination, the SSI rate decreased from 3.4% to 0.7%. These findings suggest that both ultraclean air and antimicrobial prophylaxis can reduce the incidence of SSI following orthopedic implant operations, but antimicrobial prophylaxis is more beneficial than ultraclean air. Intraoperative UV radiation has not been shown to decrease overall SSI risk.[94,312]

(2) Environmental surfaces

Environmental surfaces in U.S. operating rooms (e.g., tables, floors, walls, ceilings, lights) are rarely implicated as the sources of pathogens important in the development of SSIs. Nevertheless, it is important to perform routine cleaning of these surfaces to reestablish a clean environment after each operation.[180,212,300,302] There are no data to support routine disinfecting of environmental surfaces or equipment between operations in the absence of contamination or visible soiling. When visible soiling of surfaces or equipment occurs during an operation, an Environmental Protection Agency (EPA)-approved hospital disinfectant should be used to decontaminate the affected areas before the next operation.[180,212,300-302,313-315] This is in keeping with the Occupational Safety and Health Administration (OSHA) requirement that all equipment and environmental surfaces be cleaned and decontaminated after contact with blood or other potentially infectious materials.[315] Wet-vacuuming of the floor with an EPA-approved hospital disinfectant is performed routinely after the last operation of the day or night. Care should be taken to ensure that medical equipment left in the operating room be covered so that solutions used during cleaning and disinfecting do not contact sterile devices or equipment.[316] There are no data to support special cleaning procedures or closing of an operating room after a contaminated or dirty operation has been performed.[300,301]

Table 8 Parameters for Operating Room Ventilation, American Institute of Architects, 1996

Temperature	68-73°F, depending on normal ambient temperatures
Relative humidity	30%-60%
Air movement	From "clean to less clean" areas
Air changes	Minimum 15 total air changes per hour Minimum 3 air changes of outdoor air per hour

American Institute of Architects.[299]

Tacky mats placed outside the entrance to an operating room/suite have not been shown to reduce the number of organisms on shoes or stretcher wheels, nor do they reduce the risk of SSI.[1,179,295,301]

(3) Microbiologic sampling

Because there are no standardized parameters by which to compare microbial levels obtained from cultures of ambient air or environmental surfaces in the operating room, routine microbiologic sampling cannot be justified. Such environmental sampling should only be performed as part of an epidemiologic investigation.

(4) Conventional sterilization of surgical instruments

Inadequate sterilization of surgical instruments has resulted in SSI outbreaks.[302,317,318] Surgical instruments can be sterilized by steam under pressure, dry heat, ethylene oxide, or other approved methods. The importance of routinely monitoring the quality of sterilization procedures has been established.[1,180,212,299] Microbial monitoring of steam autoclave performance is necessary and can be accomplished by use of a biological indicator.[212,314,319] Detailed recommendations for sterilization of surgical instruments have been published.[212,314,320,321]

(5) Flash sterilization of surgical instruments

The Association for the Advancement of Medical Instrumentation defines flash sterilization as "the process designated for the steam sterilization of patient care items for immediate use."[321] During any operation, the need for emergency sterilization of equipment may arise (e.g., to reprocess an inadvertently dropped instrument). However, flash sterilization is not intended to be used for either reasons of convenience or as an alternative to purchasing additional instrument sets or to save time. Also, flash sterilization is not recommended for implantable devices(*) because of the potential for serious infections.[314,320,321]

*According to the FDA, an implantable device is a "device that is placed into a surgically or naturally formed cavity of the human body if it is intended to remain there for a period of 30 days or more."[321]

Flash sterilization is not recommended as a routine sterilization method because of the lack of timely biologic indicators to monitor performance, absence of protective packaging following sterilization, possibility for contamination of processed items during transportation to operating rooms, and use of minimal sterilization cycle parameters (i.e., time, temperature, pressure).[319] To address some of these concerns, many hospitals have placed equipment for flash sterilization in close proximity to operating rooms and new biologic indicators that provide results in 1 to 3 hours are now available for flash-sterilized items.[322-325] Nevertheless, flash sterilization should be restricted to its intended purpose until studies are performed that can demonstrate comparability with conventional sterilization methods regarding risk of SSI. Sterilization cycle parameters for flash sterilization are shown in Table 9.

b. Surgical attire and drapes

In this section the term *surgical attire* refers to scrub suits, caps/hoods, shoe covers, masks, gloves, and gowns. Although experimental data show that live microorganisms are shed from hair, exposed skin, and mucous membranes of operating room personnel,[75,181,326-330] few controlled clinical studies have evaluated the relationship between the use of surgical attire and SSI risk. Nevertheless, the use of barriers seems prudent to minimize a patient's exposure to the skin, mucous membranes, or hair of surgical team members, as well as to protect surgical team members from exposure to blood and bloodborne pathogens (e.g., human immunodeficiency virus and hepatitis viruses).

(1) Scrub suits

Surgical team members often wear a uniform called a "scrub suit" that consists of pants and a shirt. Policies for laundering, wearing, covering, and changing scrub suits vary greatly. Some policies restrict the laundering of scrub suits to the facility, while other facilities have policies that allow laundering by employees. There are no well-controlled studies evaluating scrub suit laundering as an SSI risk factor.[331] Some facilities have policies that restrict the wearing of scrub suits to the operating suite, while other facilities allow the wearing of cover gowns over scrub suits when personnel leave the suite. The Association of Operating Room Nurses recommends that scrub suits be changed after they become visibly soiled and that they be laundered only in an approved and monitored laundry facility.[212] Additionally, OSHA regulations require that "if a garment(s) is penetrated by blood or other potentially infectious materials, the garment(s) shall be removed immediately or as soon as feasible."[315]

(2) Masks

The wearing of surgical masks during operations to prevent potential microbial contamination of incisions is a longstanding surgical tradition. However, some studies have raised questions about the efficacy and cost-benefit of surgical masks in reducing SSI risk.[328,332-338] Nevertheless, wearing a mask can be beneficial since it protects the wearer's nose and mouth from inadvertent exposures (i.e., splashes) to blood and other body fluids. OSHA regulations require that masks in combination with protective eyewear, such as goggles or glasses with solid shields, or chin-length face shields be worn whenever splashes, spray, spatter, or droplets of blood or other potentially infectious material may be generated and eye, nose, or mouth contamination can be reasonably anticipated.[315] In addition, a respirator certified by the National Institute for Occupational Safety and Health with protection factor N95 or higher is required when the patient has or is suspected of having infectious tuberculosis.[339]

(3) Surgical caps/hoods and shoe covers

Surgical caps/hoods are inexpensive and reduce contamination of the surgical field by organisms shed from the hair and scalp. SSI outbreaks have occasionally been traced to organisms isolated from the hair or scalp (*S. aureus* and group A *Streptococcus*),[75,76] even when caps were worn by personnel during the operation and in the operating suites.

The use of shoe covers has never been shown to decrease SSI risk or to decrease bacteria counts on the operating room floor.[340,341] Shoe covers may, however, protect surgical team members from exposure to blood and other body fluids during an operation. OSHA regulations require that surgical caps or hoods and shoe covers or boots be worn in situations when gross contamination can reasonably be anticipated (e.g., orthopedic operations, penetrating trauma cases).[315]

(4) Sterile gloves

Sterile gloves are put on after donning sterile gowns. A strong theoretical rationale supports the wearing of sterile gloves by all scrubbed members of the surgical team. Sterile gloves are worn to minimize transmission of microorganisms from the hands of team members to patients and to prevent contamination of team members' hands with patients' blood and body fluids. If the integrity of a glove is compromised (e.g., punctured), it should be changed as promptly as safety permits.[315,342,343] Wearing two pairs of gloves (double-gloving) has been shown to reduce hand contact with patients' blood and body fluids when compared to wearing only a single pair.[344,345]

(5) Gowns and drapes

Sterile surgical gowns and drapes are used to create a barrier between the surgical field and potential sources of bacteria. Gowns are worn by all scrubbed surgical team members and drapes are placed over the

patient. There are limited data that can be used to understand the relationship of gown or drape characteristics with SSI risk. The wide variation in the products and study designs make interpretation of the literature difficult.[329,346-350]

Gowns and drapes are classified as disposable (single use) or reusable (multiple use). Regardless of the material used to manufacture gowns and drapes, these items should be impermeable to liquids and viruses.[351,352] In general, only gowns reinforced with films, coatings, or membranes appear to meet standards developed by the American Society for Testing and Materials.[351-353] However, such "liquid-proof" gowns may be uncomfortable because they also inhibit heat loss and the evaporation of sweat from the wearer's body. These factors should be considered when selecting gowns.[353,354] A discussion of the role of gowns and drapes in preventing the transmission of bloodborne pathogens is beyond the scope of this document.[355]

c. Asepsis and surgical technique

(1) Asepsis

Rigorous adherence to the principles of asepsis by all scrubbed personnel is the foundation of surgical site infection prevention. Others who work in close proximity to the sterile surgical field, such as anesthesia personnel who are separated from the field only by a drape barrier, also must abide by these principles. SSIs have occurred in which anesthesia personnel were implicated as the source of the pathogen.[34,231,234,356-358] Anesthesiologists and nurse anesthetists perform a variety of invasive procedures such as placement of intravascular devices and endotracheal tubes, and administration of intravenous drugs and solutions. Lack of adherence to the principles of asepsis during such procedures,[359] including use of common syringes[360,361] and contaminated infusion pumps,[359,362-364] and the assembly of equipment and solutions in advance of procedures,[316,360] have been associated with outbreaks of postoperative infections, including SSI. Recommendations for infection control practices in anesthesiology have been published.[212,365-367]

(2) Surgical technique

Excellent surgical technique is widely believed to reduce the risk of SSI.[26,49,179,180,368,369] Such techniques include maintaining effective hemostasis while preserving adequate blood supply, preventing hypothermia, gently handling tissues, avoiding inadvertent entries into a hollow viscus, removing devitalized (e.g., necrotic or charred) tissues, using drains and suture material appropriately, eradicating dead space, and appropriately managing the postoperative incision.

Table 9. Parameters for Flash Sterilization Cycles, Association for the Advancement of Medical Instrumentation

	Minimum Exposure Time and Temperature
Gravity-displacement	
Nonporous items	3 min at 132°C (270°F)
Nonporous and porous items	10 min at 132°C (270°F)
Prevacuum	
Nonporous items	3 min at 132°C (270°F)
Nonporous and porous items	4 min at 132°C (270°F)

Association for the Advancement of Medical Instrumentation.[321]

Any foreign body, including suture material, a prosthesis, or drain, may promote inflammation at the surgical site[94] and may increase the probability of SSI after otherwise benign levels of tissue contamination. Extensive research compares different types of suture material and their presumed relationships to SSI risk.[370-379] In general, monofilament sutures appear to have the lowest infection-promoting effects.[3,94,179,180]

A discussion of appropriate surgical drain use and details of drain placement exceed the scope of this document, but general points should be briefly noted. Drains placed through an operative incision increase incisional SSI risk.[380] Many authorities suggest placing drains through a separate incision distant from the operative incision.[283,381] It appears that SSI risk also decreases when closed suction drains are used rather than open drains.[174] Closed suction drains can effectively evacuate postoperative hematomas or seromas, but timing of drain removal is important. Bacterial colonization of initially sterile drain tracts increases with the duration of time the drain is left in place.[382]

Hypothermia in surgical patients, defined as a core body temperature below 36°C, may result from general anesthesia, exposure to cold, or intentional cooling such as is done to protect the myocardium and central nervous system during cardiac operations.[302,383,384] In one study of patients undergoing colorectal operations, hypothermia was associated with an increased SSI risk.[385] Mild hypothermia appears to increase incisional SSI risk by causing vasoconstriction, decreased delivery of oxygen to the wound space, and subsequent impairment of function of phagocytic leukocytes (i.e., neutrophils).[386-390] In animal models, supplemental oxygen administration has been shown to reverse the dysfunction of phagocytes in fresh incisions.[391] In recent human experiments, controlled local heating of incisions with an electrically powered bandage has been shown to improve tissue oxygenation.[392] Randomized clinical trials are needed to establish that measures which improve wound space oxygenation can reduce SSI risk.

4. Operative characteristics: Postoperative issues

a. Incision care

The type of postoperative incision care is determined by whether the incision is closed primarily (i.e., the skin edges are re-approximated at the end of the operation), left open to be closed later, or left open to heal by second intention. When a surgical incision is closed primarily, as most are, the incision is usually covered with a sterile dressing for 24 to 48 hours.[393,394] Beyond 48 hours, it is unclear whether an incision must be covered by a dressing or whether showering or bathing is detrimental to healing. When a surgical incision is left open at the skin level for a few days before it is closed (delayed primary closure), a surgeon has determined that it is likely to be contaminated or that the patient's condition prevents primary closure (e.g., edema at the site). When such is the case, the incision is packed with a sterile dressing. When a surgical incision is left open to heal by second intention, it is also packed with sterile moist gauze and covered with a sterile dressing. The American College of Surgeons, CDC, and others have recommended using sterile gloves and equipment (sterile technique) when changing dressings on any type of surgical incision.[180,395-397]

b. Discharge planning

In current practice, many patients are discharged very soon after their operation, before surgical incisions have fully healed.[398] The lack of optimum protocols for home incision care dictates that much of what is done at home by the patient, family, or home care agency practitioners must be individualized. The intent of discharge planning is to maintain integrity of the healing incision, educate the patient about the signs and symptoms of infection, and advise the patient about whom to contact to report any problems.

F. SSI SURVEILLANCE

Surveillance of SSI with feedback of appropriate data to surgeons has been shown to be an important component of strategies to reduce SSI risk.[16,399,400] A successful surveillance program includes the use of epidemiologically sound infection definitions (Tables 1 and 2) and effective surveillance methods, stratification of SSI rates according to risk factors associated with SSI development, and data feedback.[25]

1. SSI risk stratification

a. Concepts

Three categories of variables have proven to be reliable predictors of SSI risk: (1) those that estimate the intrinsic degree of microbial contamination of the surgical site, (2) those that measure the duration of an operation, and (3) those that serve as markers for host susceptibility.[25] A widely accepted scheme for classifying the degree of intrinsic microbial contamination of a surgical site was developed by the 1964 NAS/NRC Cooperative Research Study and modified in 1982 by CDC for use in SSI surveillance (Table 7).[2,94] In this scheme, a member of the surgical team classifies the patient's wound at the completion of the operation. Because of its ease of use and wide availability, the surgical wound classification has been used to predict SSI risk.[16,94,126,401-405] Some researchers have suggested that surgeons compare clean wound SSI rates with those of other surgeons.[16,399] However, two CDC efforts—the SENIC Project and the NNIS system—incorporated other predictor variables into SSI risk indices. These showed that even within the category of clean wounds, the SSI risk varied by risk category from 1.1% to 15.8% (SENIC) and from 1.0% to 5.4% (NNIS).[125,126] In addition, sometimes an incision is incorrectly classified by a surgical team member or not classified at all, calling into question the reliability of the classification. Therefore, reporting SSI rates stratified by wound class alone is not recommended.

Data on 10 variables collected in the SENIC Project were analyzed by using logistic regression modeling to develop a simple additive SSI risk index.[125] Four of these were found to be independently associated with SSI risk: (1) an abdominal operation, (2) an operation lasting >2 hours, (3) a surgical site with a wound classification of either contaminated or dirty/infected, and 4) an operation performed on a patient having ≥3 discharge diagnoses. Each of these equally weighted factors contributes a point when present, such that the risk index values range from 0 to 4. By using these factors, the SENIC index predicted SSI risk twice as well as the traditional wound classification scheme alone.

The NNIS risk index is operation-specific and applied to prospectively collected surveillance data. The index values range from 0 to 3 points and are defined by three independent and equally weighted variables. One point is scored for each of the following when present: (1) American Society of Anesthesiologists (ASA) Physical Status Classification of >2 (Table 10), (2) either contaminated or dirty/infected wound classification (Table 7), and (3) length of operation >T hours, where T is the approximate 75th percentile of the duration of the specific operation being performed.[126] The ASA class replaced discharge diagnoses of the SENIC risk index as a surrogate for the patient's underlying severity of illness (host susceptibility)[406,407] and has the advantage of being readily available in the chart during the patient's hospital stay. Unlike SENIC's constant 2-hour cut-point for duration of operation, the operation-specific cut-points used in the NNIS risk index increase its discriminatory power compared to the SENIC index.[126]

b. Issues

Adjustment for variables known to confound rate estimates is critical if valid comparisons of SSI rates are to be made between surgeons or hospitals.[408] Risk stratification, as described above, has proven useful for this purpose, but relies on the ability of surveillance personnel to find and record data consistently and correctly. For the three variables used in the NNIS risk index, only one study has focused on how accurately any of them are recorded. Cardo et al. found that surgical team members' accuracy in assessing wound classification for general and trauma surgery was 88% (95% CI: 82%-94%).[409] However, there are sufficient ambiguities in the wound class definitions themselves to warrant concern about the reproducibility of Cardo's results. The accuracy of recording the duration of operation (i.e., time from skin incision to skin closure) and the ASA class has not been studied. In an unpublished report from the NNIS system, there was evidence that overreporting of high ASA class existed in some hospitals. Further validation of the reliability of the recorded risk index variables is needed.

Additionally, the NNIS risk index does not adequately discriminate the SSI risk for all types of operations.[27,410] It seems likely that a combination of risk factors specific to patients undergoing an operation will be more predictive. A few studies have been performed to develop procedure-specific risk indices[218,411-414] and research in this area continues within CDC's NNIS system.

2. SSI surveillance methods

SSI surveillance methods used in both the SENIC Project and the NNIS system were designed for monitoring inpatients at acute-care hospitals. Over the past decade, the shift from inpatient to outpatient surgical care (also called ambulatory or day surgery) has been dramatic. It has been estimated that 75% of all operations in the United States will be performed in outpatient settings by the year 2000.[4] While it may be appropriate to use common definitions of SSI for inpatients and outpatients,[415] the types of operations monitored, the risk factors assessed, and the case-finding methods used may differ. New predictor variables may emerge from analyses of SSIs among outpatient surgery patients, which may lead to different ways of estimating SSI risk in this population.

The choice of which operations to monitor should be made jointly by surgeons and infection control personnel. Most hospitals do not have the resources to monitor all surgical patients all the time, nor is it likely that the same intensity of surveillance is necessary for certain low-risk procedures. Instead, hospitals should target surveillance efforts toward high-risk procedures.[416]

a. Inpatient SSI surveillance

Two methods, alone or together, have been used to identify inpatients with SSIs: (1) direct observation of the surgical site by the surgeon, trained nurse surveyor, or infection control personnel[16,97,399,402,409,417-420] and (2) indirect detection by infection control personnel through review of laboratory reports, patient records, and discussions with primary care providers.[15,84,399,402,404,409,418,421-427] The surgical literature suggests that direct observation of surgical sites is the most accurate method to detect SSIs, although sensitivity data are lacking.[16,399,402,417,418] Much of the SSI data reported in the infection control literature has been generated by indirect case-finding methods,[125,126,422,425,426,428-430] but some studies of direct methods also have been conducted.[97,409] Some studies use both methods of detection.[84,409,424,427,431] A study that focused solely on the sensitivity and specificity of SSIs detected by indirect methods found a sensitivity of 83.8% (95% CI: 75.7%-91.9%) and a specificity of 99.8% (95% CI: 99%-100%).[409] Another study showed that chart review triggered by a computer-generated report of antibiotic orders for post-cesarean section patients had a sensitivity of 89% for detecting endometritis.[432]

Indirect SSI detection can readily be performed by infection control personnel during surveillance rounds. The work includes gathering demographic, infection, surgical, and laboratory data on patients who have undergone operations of interest.[433] These data can be obtained from patients' medical records, including microbiology, histopathology, laboratory, and pharmacy data; radiology reports; and records from the operating room. Additionally, inpatient admissions, emergency room, and clinic visit records are sources of data for those postdischarge surgical patients who are readmitted or seek follow-up care.

The optimum frequency of SSI case-finding by either method is unknown and varies from daily to ≤3 times per week, continuing until the patient is discharged from the hospital. Because duration of hospitalization is often very short, postdischarge SSI surveillance has

Table 10. Physical Status Classification, American Society of Anesthesiologists*

Code	Patient's Preoperative Physical Status
1	Normally healthy patient
2	Patient with mild systemic disease
3	Patient with severe systemic disease that is not incapacitating
4	Patient with an incapacitating systemic disease that is a constant threat to life
5	Moribund patient who is not expected to survive for 24 hours with or without operation

*Reference 406.
Note: The above is the version of the ASA Physical Status Classification System that was current at the time of development of, and still is used in, the NNIS Risk Index. Meanwhile, the American Society of Anesthesiologists has revised their classification system; the most recent version is available at *http://www.asahq.org/profinfo/physical status.html*.

become increasingly important to obtain accurate SSI rates (refer to "Postdischarge SSI Surveillance" section).

To calculate meaningful SSI rates, data must be collected on all patients undergoing the operations of interest (i.e., the population at risk). Because one of its purposes is to develop strategies for risk stratification, the NNIS system collects the following data on all surgical patients surveyed: operation date; NNIS operative procedure category;[434] surgeon identifier; patient identifier; age and sex; duration of operation; wound class; use of general anesthesia; ASA class; emergency; trauma; multiple procedures; endoscopic approach; and discharge date.[433] With the exception of discharge date, these data can be obtained manually from operating room logs or be electronically downloaded into surveillance software, thereby substantially reducing manual transcription and data entry errors.[433] Depending on the needs for risk-stratified SSI rates by personnel in infection control, surgery, and quality assurance, not all data elements may be pertinent for every type of operation. At minimum, however, variables found to be predictive of increased SSI risk should be collected (refer to "SSI Risk Stratification" section).

b. Postdischarge SSI surveillance

Between 12% and 84% of SSIs are detected after patients are discharged from the hospital.[98,337,402,428,435-454] At least two studies have shown that most SSIs become evident within 21 days after operation.[446,447] Since the length of postoperative hospitalization continues to decrease, many SSIs may not be detected for several weeks after discharge and may not require readmission to the operating hospital. Dependence solely on inpatient case-finding will result in underestimates of SSI rates for some operations (e.g., coronary artery bypass graft) (CDC/NNIS system, unpublished data, 1998). Any comparison of SSI rates must take into account whether case-finding included SSIs detected after discharge. For comparisons to be valid, even in the same institution over time, the postdischarge surveillance methods must be the same.

Postdischarge surveillance methods have been used with varying degrees of success for different procedures and among hospitals and include (1) direct examination of patients' wounds during follow-up visits to either surgery clinics or physicians' offices,[150,399,402,404,430,436,440,441,447,452,455] (2) review of medical records of surgery clinic patients,[404,430,439] (3) patient surveys by mail or telephone,[435,437,438,441,442,444,445,448,449,455-457] or (4) surgeon surveys by mail or telephone.[98,428,430,437-439,443,444,446,448,450,451,455] One study found that patients have difficulty assessing their own wounds for infection (52% specificity, 26% positive predictive value),[458] suggesting that data obtained by patient questionnaire may inaccurately represent actual SSI rates.

Recently, Sands et al. performed a computerized search of three databases to determine which best identified SSIs: ambulatory encounter records for diagnostic, testing, and treatment codes; pharmacy records for specific antimicrobial prescriptions; and administrative records for rehospitalizations and emergency room visits.[446] This study found that pharmacy records indicating a patient had received antimicrobial agents commonly used to treat soft tissue infections had the highest sensitivity (50%) and positive predictive value (19%), although even this approach alone was not very effective.

As integrated health information systems expand, tracking surgical patients through the entire course of care may become more feasible, practical, and effective. At this time, no consensus exists on which postdischarge surveillance methods are the most sensitive, specific, and practical. Methods chosen will necessarily reflect the hospital's unique mix of operations, personnel resources, and data needs.

c. Outpatient SSI surveillance

Both direct and indirect methods have been used to detect SSIs that complicate outpatient operations. One 8-year study of operations for hernia and varicose veins used home visits by district health nurses combined with a survey completed by the surgeon at the patient's 2-week postoperative clinic visit to identify SSIs.[459] While ascertainment was essentially 100%, this method is impractical for widespread implementation. High response rates have been obtained from questionnaires mailed to surgeons (72%->90%).[443,444,446,455,459-461] Response rates from telephone questionnaires administered to patients were more variable (38%,[444] 81%,[457] and 85%[455]), and response rates from questionnaires mailed to patients were quite low (15%[455] and 33%[446]). At this time, no single detection method can be recommended. Available resources and data needs determine which method(s) should be used and which operations should be monitored. Regardless of which detection method is used, it is recommended that the CDC NNIS definitions of SSI (Tables 1 and 2) be used without modification in the outpatient setting.

G. GUIDELINE EVALUATION PROCESS

The value of the HICPAC guidelines is determined by those who use them. To help assess that value, HICPAC is developing an evaluation tool to learn how guidelines meet user expectations, and how and when these guidelines are disseminated and implemented.

AJIC
Volume 27, Number 2

II. Recommendations for prevention of surgical site infection

A. RATIONALE

The Guideline for Prevention of Surgical Site Infection, 1999, provides recommendations concerning reduction of surgical site infection risk. Each recommendation is categorized on the basis of existing scientific data, theoretical rationale, and applicability. However, the previous CDC system for categorizing recommendations has been modified slightly.

Category I recommendations, including IA and IB, are those recommendations that are viewed as effective by HICPAC and experts in the fields of surgery, infectious diseases, and infection control. Both Category IA and IB recommendations are applicable for, and should be adopted by, all healthcare facilities; IA and IB recommendations differ only in the strength of the supporting scientific evidence.

Category II recommendations are supported by less scientific data than Category I recommendations; such recommendations may be appropriate for addressing specific nosocomial problems or specific patient populations.

No recommendation is offered for some practices, either because there is a lack of consensus regarding their efficacy or because the available scientific evidence is insufficient to support their adoption. For such unresolved issues, practitioners should use judgement to determine a policy regarding these practices within their organization. Recommendations that are based on federal regulation are denoted with an asterisk.

B. RANKINGS

Category IA. Strongly recommended for implementation and supported by well-designed experimental, clinical, or epidemiological studies.

Category IB. Strongly recommended for implementation and supported by some experimental, clinical, or epidemiological studies and strong theoretical rationale.

Category II. Suggested for implementation and supported by suggestive clinical or epidemiological studies or theoretical rationale.

No recommendation; unresolved issue. Practices for which insufficient evidence or no consensus regarding efficacy exists.

Practices required by federal regulation are denoted with an asterisk (*).

C. RECOMMENDATIONS

1. Preoperative

a. Preparation of the patient

1. Whenever possible, identify and treat all infections remote to the surgical site before elective operation and postpone elective operations on patients with remote site infections until the infection has resolved. *Category IA*
2. Do not remove hair preoperatively unless the hair at or around the incision site will interfere with the operation. *Category IA*
3. If hair is removed, remove immediately before the operation, preferably with electric clippers. *Category IA*
4. Adequately control serum blood glucose levels in all diabetic patients and particularly avoid hyperglycemia perioperatively. *Category IB*
5. Encourage tobacco cessation. At minimum, instruct patients to abstain for at least 30 days before elective operation from smoking cigarettes, cigars, pipes, or any other form of tobacco consumption (e.g., chewing/dipping). *Category IB*
6. Do not withhold necessary blood products from surgical patients as a means to prevent SSI. *Category IB*
7. Require patients to shower or bathe with an antiseptic agent on at least the night before the operative day. *Category IB*
8. Thoroughly wash and clean at and around the incision site to remove gross contamination before performing antiseptic skin preparation. *Category IB*
9. Use an appropriate antiseptic agent for skin preparation (Table 6). *Category IB*
10. Apply preoperative antiseptic skin preparation in concentric circles moving toward the periphery. The prepared area must be large enough to extend the incision or create new incisions or drain sites, if necessary. *Category II*
11. Keep preoperative hospital stay as short as possible while allowing for adequate preoperative preparation of the patient. *Category II*
12. No recommendation to taper or discontinue systemic steroid use (when medically permissible) before elective operation. *Unresolved issue*

13. No recommendation to enhance nutritional support for surgical patients solely as a means to prevent SSI. *Unresolved issue*
14. No recommendation to preoperatively apply mupirocin to nares to prevent SSI. *Unresolved issue*
15. No recommendation to provide measures that enhance wound space oxygenation to prevent SSI. *Unresolved issue*

b. Hand/forearm antisepsis for surgical team members

1. Keep nails short and do not wear artificial nails. *Category IB*
2. Perform a preoperative surgical scrub for at least 2 to 5 minutes using an appropriate antiseptic (Table 6). Scrub the hands and forearms up to the elbows. *Category IB*
3. After performing the surgical scrub, keep hands up and away from the body (elbows in flexed position) so that water runs from the tips of the fingers toward the elbows. Dry hands with a sterile towel and don a sterile gown and gloves. *Category IB*
4. Clean underneath each fingernail prior to performing the first surgical scrub of the day. *Category II*
5. Do not wear hand or arm jewelry. *Category II*
6. No recommendation on wearing nail polish. *Unresolved Issue*

c. Management of infected or colonized surgical personnel

1. Educate and encourage surgical personnel who have signs and symptoms of a transmissible infectious illness to report conditions promptly to their supervisory and occupational health service personnel. *Category IB*
2. Develop well-defined policies concerning patient-care responsibilities when personnel have potentially transmissible infectious conditions. These policies should govern (a) personnel responsibility in using the health service and reporting illness, (b) work restrictions, and (c) clearance to resume work after an illness that required work restriction. The policies also should identify persons who have the authority to remove personnel from duty. *Category IB*
3. Obtain appropriate cultures from, and exclude from duty, surgical personnel who have draining skin lesions until infection has been ruled out or personnel have received adequate therapy and infection has resolved. *Category IB*
4. Do not routinely exclude surgical personnel who are colonized with organisms such as *S. aureus* (nose, hands, or other body site) or group A *Streptococcus*, unless such personnel have been linked epidemiologically to dissemination of the organism in the healthcare setting. *Category IB*

d. Antimicrobial prophylaxis

1. Administer a prophylactic antimicrobial agent only when indicated, and select it based on its efficacy against the most common pathogens causing SSI for a specific operation (Table 4) and published recommendations.[266,268,269,282-284] *Category IA*
2. Administer by the intravenous route the initial dose of prophylactic antimicrobial agent, timed such that a bactericidal concentration of the drug is established in serum and tissues when the incision is made. Maintain therapeutic levels of the agent in serum and tissues throughout the operation and until, at most, a few hours after the incision is closed in the operating room. *Category IA*
3. Before elective colorectal operations in addition to d2 above, mechanically prepare the colon by use of enemas and cathartic agents. Administer nonabsorbable oral antimicrobial agents in divided doses on the day before the operation. *Category IA*
4. For high-risk cesarean section, administer the prophylactic antimicrobial agent immediately after the umbilical cord is clamped. *Category IA*
5. Do not routinely use vancomycin for antimicrobial prophylaxis. *Category IB*

2. Intraoperative

a. Ventilation

1. Maintain positive-pressure ventilation in the operating room with respect to the corridors and adjacent areas. *Category IB*
2. Maintain a minimum of 15 air changes per hour, of which at least 3 should be fresh air. *Category IB*
3. Filter all air, recirculated and fresh, through the appropriate filters per the American Institute of Architects' recommendations.[299] *Category IB*
4. Introduce all air at the ceiling, and exhaust near the floor. *Category IB*
5. Do not use UV radiation in the operating room to prevent SSI. *Category IB*
6. Keep operating room doors closed except as needed for passage of equipment, personnel, and the patient. *Category IB*
7. Consider performing orthopedic implant operations in operating rooms supplied with ultraclean air. *Category II*
8. Limit the number of personnel entering the operating room to necessary personnel. *Category II*

b. Cleaning and disinfection of environmental surfaces

1. When visible soiling or contamination with blood or other body fluids of surfaces or equipment occurs during an operation, use an EPA-approved hospital disinfectant to clean the affected areas before the next operation. *Category IB**

2. Do not perform special cleaning or closing of operating rooms after contaminated or dirty operations. *Category IB*
3. Do not use tacky mats at the entrance to the operating room suite or individual operating rooms for infection control. *Category IB*
4. Wet vacuum the operating room floor after the last operation of the day or night with an EPA-approved hospital disinfectant. *Category II*
5. No recommendation on disinfecting environmental surfaces or equipment used in operating rooms between operations in the absence of visible soiling. *Unresolved issue*

c. Microbiologic sampling

1. Do not perform routine environmental sampling of the operating room. Perform microbiologic sampling of operating room environmental surfaces or air only as part of an epidemiologic investigation. *Category IB*

d. Sterilization of surgical instruments

1. Sterilize all surgical instruments according to published guidelines.[212,299,314,321] *Category IB*
2. Perform flash sterilization only for patient care items that will be used immediately (e.g., to reprocess an inadvertently dropped instrument). Do not use flash sterilization for reasons of convenience, as an alternative to purchasing additional instrument sets, or to save time. *Category IB*

e. Surgical attire and drapes

1. Wear a surgical mask that fully covers the mouth and nose when entering the operating room if an operation is about to begin or already under way, or if sterile instruments are exposed. Wear the mask throughout the operation. *Category IB**
2. Wear a cap or hood to fully cover hair on the head and face when entering the operating room. *Category IB**
3. Do not wear shoe covers for the prevention of SSI. *Category IB**
4. Wear sterile gloves if a scrubbed surgical team member. Put on gloves after donning a sterile gown. *Category IB**
5. Use surgical gowns and drapes that are effective barriers when wet (i.e., materials that resist liquid penetration). *Category IB*
6. Change scrub suits that are visibly soiled, contaminated, and/or penetrated by blood or other potentially infectious materials. *Category IB**
7. No recommendations on how or where to launder scrub suits, on restricting use of scrub suits to the operating suite, or for covering scrub suits when out of the operating suite. *Unresolved issue*

f. Asepsis and surgical technique

*Federal regulation: OSHA

1. Adhere to principles of asepsis when placing intravascular devices (e.g., central venous catheters), spinal or epidural anesthesia catheters, or when dispensing and administering intravenous drugs. *Category IA*
2. Assemble sterile equipment and solutions immediately prior to use. *Category II*
3. Handle tissue gently, maintain effective hemostasis, minimize devitalized tissue and foreign bodies (i.e., sutures, charred tissues, necrotic debris), and eradicate dead space at the surgical site. *Category IB*
4. Use delayed primary skin closure or leave an incision open to heal by second intention if the surgeon considers the surgical site to be heavily contaminated (e.g., Class III and Class IV). *Category IB*
5. If drainage is necessary, use a closed suction drain. Place a drain through a separate incision distant from the operative incision. Remove the drain as soon as possible. *Category IB*

3. Postoperative incision care

a. Protect with a sterile dressing for 24 to 48 hours postoperatively an incision that has been closed primarily. *Category IB*
b. Wash hands before and after dressing changes and any contact with the surgical site. *Category IB*
c. When an incision dressing must be changed, use sterile technique. *Category II*
d. Educate the patient and family regarding proper incision care, symptoms of SSI, and the need to report such symptoms. *Category II*
e. No recommendation to cover an incision closed primarily beyond 48 hours, nor on the appropriate time to shower or bathe with an uncovered incision. *Unresolved Issue*

4. Surveillance

a. Use CDC definitions of SSI (Table 1) without modification for identifying SSI among surgical inpatients and outpatients. *Category IB*
b. For inpatient case-finding (including readmissions), use direct prospective observation, indirect prospective detection, or a combination of both direct and indirect methods for the duration of the patient's hospitalization. *Category IB*
c. When postdischarge surveillance is performed for detecting SSI following certain operations (e.g., coronary artery bypass graft), use a method that accommodates available resources and data needs. *Category II*
d. For outpatient case-finding, use a method that accommodates available resources and data needs. *Category IB*
e. Assign the surgical wound classification upon

completion of an operation. A surgical team member should make the assignment. *Category II*

f. For each patient undergoing an operation chosen for surveillance, record those variables shown to be associated with increased SSI risk (e.g., surgical wound class, ASA class, and duration of operation). *Category IB*

g. Periodically calculate operation-specific SSI rates stratified by variables shown to be associated with increased SSI risk (e.g., NNIS risk index). *Category IB*

h. Report appropriately stratified, operation-specific SSI rates to surgical team members. The optimum frequency and format for such rate computations will be determined by stratified case-load sizes (denominators) and the objectives of local, continuous quality improvement initiatives. *Category IB*

i. No recommendation to make available to the infection control committee coded surgeon-specific data. *Unresolved issue*

The Hospital Infection Control Practices Committee thanks the following subject-matter experts for reviewing a preliminary draft of this guideline: Carol Applegeet, RN, MSN, CNOR, CNAA, FAAN; Ona Baker, RN, MSHA; Philip Barie, MD, FACS; Arnold Berry, MD; Col. Nancy Bjerke, BSN, MPH, CIC; John Bohnen, MD, FRCSC, FACS; Robert Condon, MS, MD, FACS; E. Patchen Dellinger, MD, FACS; Terrie Lee, RN, MS, MPH, CIC; Judith Mathias, RN; Anne Matlow, MD, MS, FRCPC; C. Glen Mayhall, MD; Rita McCormick, RN, CIC; Ronald Nichols, MD, FACS; Barbara Pankratz, RN; William Rutala, PhD, MPH, CIC; Julie Wagner, RN; Samuel Wilson, MD, FACS. The opinions of all the reviewers might not be reflected in all the recommendations contained in this document.

The authors thank Connie Alfred, Estella Cormier, Karen Friend, Charlene Gibson, and Geraldine Jones for providing invaluable assistance.

References

1. Garner JS. CDC guideline for prevention of surgical wound infections, 1985. Supercedes guideline for prevention of surgical wound infections published in 1982. (Originally published in 1995). Revised. Infect Control 1986;7(3):193-200.
2. Simmons BP. Guideline for prevention of surgical wound infections. Infect Control 1982;3:185-196.
3. Garner JS. The CDC Hospital Infection Control Practices Advisory Committee. Am J Infect Control 1993;21:160-2.
4. Hecht AD. Creating greater efficiency in ambulatory surgery. J Clin Anesth 1995;7:581-4.
5. Horwitz JR, Chwals WJ, Doski JJ, Suescun EA, Cheu HW, Lally KP. Pediatric wound infections: a prospective multicenter study. Ann Surg 1998;227:553-8.
6. Golub R, Siddiqui F, Pohl D. Laparoscopic versus open appendectomy: a metaanalysis. J Am Coll Surg 1998;186:545-53.
7. Mayol J, Garcia-Aguilar J, Ortiz-Oshiro E, De-Diego Carmona JA, Ferndandez-Represa JA. Risks of the minimal access approach for laparoscopic surgery: multivariate analysis of morbidity related to umbilical trocar insertion. World J Surg 1997;21:529-33.
8. Lacy AM, Garcia-Valdecasas JC, Delgado S, Grande L, Fuster J, Tabet J, et al. Postoperative complications of laparoscopic-assisted colectomy. Surg Endosc 1997;11:119-22.
9. Pagni S, Salloum EJ, Tobin GR, VanHimbergen DJ, Spence PA. Serious wound infections after minimally invasive coronary bypass procedures. Ann Thorac Surg 1998;66:92-4.
10. The Southern Surgeons Club. A prospective analysis of 1518 laparoscopic cholecystectomies. N Engl J Med 1991;324:1073-8.
11. Centers for Disease Control and Prevention. National Nosocomial Infections Surveillance (NNIS) report, data summary from October 1986-April 1997, issued May 1997. Am J Infect Control 1997;25:477-87.
12. Food and Drug Administration. Topical antimicrobial drug products for over-the-counter human use: tentative final monograph for health-care antiseptic drug products—proposed rule (21 CFR Parts 333 and 369). Federal Register 1994; 59:31441-52.
13. Centers for Disease Control and Prevention, National Center for Health Statistics. Vital and Health Statistics, Detailed Diagnoses and Procedures, National Hospital Discharge Survey, 1994. Vol 127. Hyattsville, Maryland: DHHS Publication; 1997.
14. Emori TG, Gaynes RP. An overview of nosocomial infections, including the role of the microbiology laboratory. Clin Microbiol Rev 1993;6(4):428-42.
15. Cruse P. Wound infection surveillance. Rev Infect Dis 1981;4(3):734-7.
16. Cruse PJ, Foord R. The epidemiology of wound infection: a 10-year prospective study of 62,939 wounds. Surg Clin North Am 1980;60(1):27-40.
17. Martone WJ, Jarvis WR, Culver DH, Haley RW. Incidence and nature of endemic and epidemic nosocomial infections. In: Bennett JV, Brachman PS, eds. Hospital Infections. 3rd ed. Boston: Little, Brown and Co; 1992. p. 577-96.
18. Boyce JM, Potter-Bynoe G, Dziobek L. Hospital reimbursement patterns among patients with surgical wound infections following open heart surgery. Infect Control Hosp Epidemiol 1990;11(2):89-93.
19. Poulsen KB, Bremmelgaard A, Sorensen AI, Raahave D, Petersen JV. Estimated costs of postoperative wound infections. A case-control study of marginal hospital and social security costs. Epidemiol Infect 1994;113(2):283-95.
20. Vegas AA, Jodra VM, Garcia ML. Nosocomial infection in surgery wards: a controlled study of increased duration of hospital stays and direct cost of hospitalization. Eur J Epidemiol 1993;9(5):504-10.
21. Albers BA, Patka P, Haarman HJ, Kostense PJ. Cost effectiveness of preventive antibiotic administration for lowering risk of infection by 0.25%. [German]. Unfallchirurg 1994;97(12):625-8.
22. Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG. CDC definitions of nosocomial surgical site infections, 1992: a modification of CDC definitions of surgical wound infections. Infect Control Hosp Epidemiol 1992;13(10):606-8.
23. Ehrenkranz NJ, Richter EI, Phillips PM, Shultz JM. An apparent excess of operative site infections: analyses to evaluate false-positive diagnoses. Infect Control Hosp Epidemiol 1995;16(12):712-6.
24. Taylor G, McKenzie M, Kirkland T, Wiens R. Effect of surgeon's diagnosis on surgical wound infection rates. Am J Infect Control 1990;18(5):295-9.
25. SHEA, APIC, CDC, SIS. Consensus paper on the surveillance of surgical wound infections. Infect Control Hosp Epidemiol 1992;13(10):599-605.
26. Nooyen SM, Overbeek BP, Brutel de la Riviere A, Storm AJ, Langemeyer JM. Prospective randomised comparison of single-dose versus multiple-dose cefuroxime for prophylaxis in coronary artery bypass grafting. Eur J Clin Microbiol Infect Dis 1994;13:1033-7.
27. Centers for Disease Control and Prevention. National Nosocomial Infections Surveillance (NNIS) report, data summary from October 1986-April 1996, issued May 1996. A report from the National Nosocomial Infections Surveillance (NNIS) System. Am J Infect Control 1996;24:380-8.

28. Schaberg DR. Resistant gram-positive organisms. Ann Emerg Med 1994;24(3):462-4.
29. Schaberg DR, Culver DH, Gaynes RP. Major trends in the microbial etiology of nosocomial infection. Am J Med 1991;91(3B):72S-5S.
30. Jarvis WR. Epidemiology of nosocomial fungal infections, with emphasis on *Candida* species. Clin Infect Dis 1995;20:1526-30.
31. Centers for Disease Control. Nosocomial outbreak of *Rhizopus* infections associated with Elastoplast wound dressings—Minnesota. MMWR 1978;27:33-4.
32. Pearson RD, Valenti WM, Steigbigel RT. *Clostridium perfringens* wound infections associated with elastic bandages. JAMA 1980;244:1128-30.
33. Richet HM, Craven PC, Brown JM, Lasker BA, Cox CD, McNeil MM, et al. A cluster of *Rhodococcus (Gordona) bronchialis* sternal-wound infections after coronary-artery bypass surgery. N Engl J Med 1991;324:104-9.
34. Wenger PN, Brown JM, McNeil MM, Jarvis WR. *Nocardia farcinica* sternotomy site infections in patients following open heart surgery. J Infect Dis 1998;178:1539-43.
35. Lowry PW, Blankenship RJ, Gridley W, Troup NJ, Tompkins LS. A cluster of *Legionella* sternal-wound infections due to postoperative topical exposure to contaminated tap water. N Engl J Med 1991;324:109-13.
36. Bassett DC, Stokes KJ, Thomas WR. Wound infection with *Pseudomonas multivorans:* a water-borne contaminant of disinfectant solutions. Lancet 1970;1:1188-91.
37. Cruse PJ. Surgical wound infection. In: Wonsiewicz MJ, ed. Infectious Diseases. Philadelphia: W.B.Saunders Co; 1992. p. 758-64.
38. Altemeier WA, Culbertson WR. Surgical infection. In: Moyer CA, Rhoads JE, Allen JG, Harkins HN, eds. Surgery, principles and practice. 3rd ed. Philadelphia: JB Lippincott; 1965. p. 51-77.
39. Krizek TJ, Robson MC. Evolution of quantitative bacteriology in wound management. Am J Surg 1975;130:579-84.
40. Elek SD, Conen PE. The virulence of *Staphylococcus pyogenes* for man: a study of problems with wound infection. Br J Exp Pathol 1957;38:573-86.
41. Noble WC. The production of subcutaneous staphylococcal skin lesions in mice. Br J Exp Pathol 1965;46:254-62.
42. James RC, MacLeod CJ. Induction of staphylococcal infections in mice with small inocula introduced on sutures. Br J Exp Pathol 1961;42:266-77.
43. Henderson B, Poole S, Wilson M. Microbial/host interactions in health and disease: who controls the cytokine network? Immunopharmacology 1996;35:1-21.
44. Morrison DC, Ryan JL. Endotoxins and disease mechanisms. Ann Rev Med 1987;38:417-32.
45. Demling R, LaLonde C, Saldinger P, Knox J. Multiple-organ dysfunction in the surgical patient: pathophysiology, prevention, and treatment. Curr Probl Surg 1993;30:345-414.
46. Eiseman B, Beart R, Norton L. Multiple organ failure. Surg Gynecol Obstet 1977;14:323-6.
47. Fry DE, Pearlstein L, Fulton RL, Polk HC, Jr. Multiple system organ failure: the role of uncontrolled infection. Arch Surg 1980;115:136-40.
48. Kasper DL. Bacterial capsule—old dogmas and new tricks. J Infect Dis 1986;153:407-15.
49. Dellinger EP. Surgical infections and choice of antibiotics. In: Sabiston DC, ed. Textbook of Surgery. The Biological Basis of Modern Surgical Practice. 15 ed. Philadelphia: W.B.Saunders Co; 1997. p. 264-80.
50. Goeau-Brissonniere O, Leport C, Guidoin R, Lebrault C, Pechere JC, Bacourt F. Experimental colonization of an expanded polytetrafluoroethylene vascular graft with *Staphylococcus aureus*: a quantitative and morphologic study. J Vasc Surg 1987;5(5):743-8.
51. Bergamini TM, Corpus RA Jr., Brittian KR, Peyton JC, Cheadle WG. The natural history of bacterial biofilm graft infection. J Surg Res 1994;56:393-6.
52. Baddour LM, Christensen GD, Hester MG, Bisno AL. Production of experimental endocarditis by coagulase-negative staphylococci: variability in species virulence. J Infect Dis 1984;150:721-7.
53. Christensen GD, Baddour LM, Simpson WA. Phenotypic variation of *Staphylococcus epidermidis* slime production in vitro and in vivo. Infect Immun 1987;55:2870-7.
54. Mayberry-Carson KJ, Tober-Meyer B, Smith JK, Lambe DW Jr., Costerton JW. Bacterial adherence and glycocalyx formation in osteomyelitis experimentally induced with *Staphylococcus aureus*. Infect Immun 1984;43:825-33.
55. Mills J, Pulliam L, Dall L, Marzouk J, Wilson W, Costerton JW. Exopolysaccharide production by *viridans streptococci* in experimental endocarditis. Infect Immun 1984;43:359-67.
56. Kaebnick HW, Bandyk DF, Bergamini TM, Towne JB. The microbiology of explanted vascular prostheses. Surgery 1987;102:756-61.
57. Altemeier WA, Culbertson WR, Hummel RP. Surgical considerations of endogenous infections—sources, types, and methods of control. Surg Clin North Am 1968;48:227-40.
58. Wiley AM, Ha'eri GB. Routes of infection: a study of using "tracer particles" in the orthopedic operating room. Clin Orthop 1979;139:150-5.
59. Slaughter L, Morris JE, Starr A. Prosthetic valvular endocarditis. A 12-year review. Circulation 1973;47:1319-26.
60. Carlsson AK, Lidgren L, Lindberg L. Prophylactic antibiotics against early and late deep infections after total hip replacements. Acta Orthop Scand 1977;48:405-10.
61. Hunter JG, Padilla M, Cooper-Vastola S. Late *Clostridium perfringens* breast implant infection after dental treatment. Ann Plast Surg 1996;36(3):309-12.
62. Stuesse DC, Robinson JH, Durzinsky DS. A late sternal wound infection caused by hematogenous spread of bacteria. Chest 1995;108(6):1742-3.
63. Howe CW. Experimental wound sepsis from transient *Escherichia coli* bacteremia. Surgery 1969;66:570-4.
64. Velasco E, Thuler LC, Martins CA, Dias LM, Conalves VM. Risk factors for infectious complications after abdominal surgery for malignant disease. Am J Infect Control 1996;24(1):1-6.
65. Bruun JN. Post-operative wound infection. Predisposing factors and the effect of a reduction in the dissemination of staphylococci. Acta Med Scand Suppl 1970;514(Suppl):3-89.
66. Simchen E, Rozin R, Wax Y. The Israeli Study of Surgical Infection of drains and the risk of wound infection in operations for hernia. Surg Gynecol Obstet 1990;170:331-7.
67. Edwards LD. The epidemiology of 2056 remote site infections and 1966 surgical wound infections occurring in 1865 patients: a four year study of 40,923 operations at Rush-Presbyterian-St. Luke's Hospital, Chicago. Ann Surg 1976;184:758-66.
68. Valentine RJ, Weigelt JA, Dryer D, Rodgers C. Effect of remote infections on clean wound infection rates. Am J Infect Control 1986;14:64-7.
69. Cioffi GA, Terezhalmy GT, Taybos GM. Total joint replacement: a consideration for antimicrobial prophylaxis. Oral Surg Oral Med Oral Pathol 1988;66(1):124-9.
70. Heggeness MH, Esses SI, Errico T, Yuan HA. Late infection of spinal instrumentation by hematogenous seeding. Spine 1993;18(4):492-6.
71. Mont MA, Waldman B, Banerjee C, Pacheco IH, Hungerford DS. Multiple irrigation, debridement, and retention of components in infected total knee arthroplasty. J Arthroplasty 1997;12(4):426-33.
72. Ozuna RM, Delamarter RB. Pyogenic vertebral osteomyelitis and postsurgical disc space infections. Ortho Clin North Am 1996;27(1):87-94.

73. Schmalzried TP, Amstutz HC, Au MK, Dorey FJ. Etiology of deep sepsis in total hip arthroplasty. The significance of hematogenous and recurrent infections. Clin Orthop 1992;280:200-7.
74. Calia FM, Wolinsky E, Mortimer EA Jr., Abrams JS, Rammelkamp CH Jr. Importance of the carrier state as a source of *Staphylococcus aureus* in wound sepsis. J Hyg (Lond) 1969;67:49-57.
75. Dineen P, Drusin L. Epidemics of postoperative wound infections associated with hair carriers. Lancet 1973;2(7839):1157-9.
76. Mastro TD, Farley TA, Elliott JA, Facklam RR, Perks JR, Hadler JL, et al. An outbreak of surgical-wound infections due to group A *streptococcus* carried on the scalp. N Engl J Med 1990;323:968-72.
77. Ford CR, Peterson DE, Mitchell CR. An appraisal of the role of surgical face masks. Am J Surg 1967;113:787-90.
78. Letts RM, Doermer E. Conversation in the operating theater as a cause of airborne bacterial contamination. J Bone Joint Surg [Am] 1983;65:357-62.
79. Giamarellou H, Antoniadou A. Epidemiology, diagnosis, and therapy of fungal infections in surgery. Infect Control Hosp Epidemiol 1996;17(8):558-64.
80. Lee JT. Surgical wound infections: surveillance for quality improvement. In: Fry DE, ed. Surgical Infections. Boston: Little, Brown and Co; 1995. p. 145-59.
81. Perl TM, Golub JE. New approaches to reduce *Staphylococcus aureus* nosocomial infection rates: treating *S. aureus* nasal carriage. Ann Pharmacother 1998;32:S7-S16.
82. Kluytmans JA, Mouton JW, Ijzerman EP, Vandenbroucke-Grauls CM, Maat AW, Wagenvoort JH, et al. Nasal carriage of *Staphylococcus aureus* as a major risk factor for wound infections after cardiac surgery. J Infect Dis 1995;171:216-9.
83. Perl TM, Cullen JJ, Pfaller MA, Wenzel RP, Herwaldt LA, The MARS Study Team. A randomized, double-blind, placebo-controlled clinical trial of intranasal mupirocin ointment (IM) for prevention of *S. aureus* surgical site infections (SSI) [abstract]. Abstracts of the IDSA 36th Annual Meeting 1998;91(88).
84. Gil-Egea MJ, Pi-Sunyer MT, Verdaguer A, Sanz F, Sitges-Serra A, Eleizegui LT. Surgical wound infections: prospective study of 4,486 clean wounds. Infect Control 1987;8(7):277-80.
85. Nagachinta T, Stephens M, Reitz B, Polk BF. Risk factors for surgical-wound infection following cardiac surgery. J Infect Dis 1987;156:967-73.
86. Lilienfeld DE, Vlahov D, Tenney JH, McLaughlin JS. Obesity and diabetes as risk factors for postoperative wound infections after cardiac surgery. Am J Infect Control 1988;16:3-6.
87. Slaughter MS, Olson MM, Lee JT Jr., Ward HB. A fifteen-year wound surveillance study after coronary artery bypass. Ann Thorac Surg 1993;56(5):1063-8.
88. Bryan AJ, Lamarra M, Angelini GD, West RR, Breckenridge IM. Median sternotomy wound dehiscence: a retrospective case control study of risk factors and outcome. J R Coll Surg Edinb 1992;37:305-8.
89. Jones JK, Triplett RG. The relationship of cigarette smoking to impaired intraoral wound healing: a review of evidence and implications for patient care. J Oral Maxillofac Surg 1992;50(3):237-9; discussion 239-40.
90. Vinton AL, Traverso LW, Jolly PC. Wound complications after modified radical mastectomy compared with tylectomy with axillary lymph node dissection. Am J Surg 1991;161(5):584-8.
91. Holley DT, Toursarkissian B, Vansconez HC, Wells MD, Kenady DE, Sloan DA. The ramifications of immediate reconstruction in the management of breast cancer. Am Surg 1995;61(1):60-5.
92. Beitsch P, Balch C. Operative morbidity and risk factor assessment in melanoma patients undergoing inguinal lymph node dissection. Am J Surg 1992;164(5):462-6; discussion 465-6.
93. Post S, Betzler M, vonDitfurth B, Schurmann G, Kuppers P, Herfarth C. Risks of intestinal anastomoses in Crohn's disease. Ann Surg 1991;213(1):37-42.
94. B'erard F, Gandon J. Postoperative wound infections: the influence of ultraviolet irradiation of the operating room and of various other factors. Ann Surg 1964;160(Suppl 1):1-192.
95. Nystrom PO, Jonstam A, Hojer H, Ling L. Incisional infection after colorectal surgery in obese patients. Acta Chir Scand 1987;153:225-7.
96. He GW, Ryan WH, Acuff TE, Bowman RT, Douthit MB, Yang CQ, et al. Risk factors for operative mortality and sternal wound infection in bilateral internal mammary artery grafting. J Thorac Cardiovasc Surg 1994;107(1):196-202.
97. Barber GR, Miransky J, Brown AE, Coit DG, Lewis FM, Thaler HT, et al. Direct observations of surgical wound infections at a comprehensive cancer center. Arch Surg 1995;130(10):1042-7.
98. Cruse PJ, Foord R. A five-year prospective study of 23,649 surgical wounds. Arch Surg 1973;107:206-10.
99. Claesson BE, Holmlund DE. Predictors of intraoperative bacterial contamination and postoperative infection in elective colorectal surgery. J Hosp Infect 1988;11:127-35.
100. Mishriki SF, Law DJ, Jeffery PJ. Factors affecting the incidence of postoperative wound infection. J Hosp Infect 1990;16:223-30.
101. Doig CM, Wilkinson AW. Wound infection in a children's hospital. Br J Surg 1976;63:647-50.
102. Sharma LK, Sharma PK. Postoperative wound infection in a pediatric surgical service. J Pediatr Surg 1986;21:889-91.
103. Casey J, Flinn WR, Yao JS, Fahey V, Pawlowski J, Bergan JJ. Correlation of immune and nutritional status with wound complications in patients undergoing vascular operations. Surgery 1983;93(6):822-7.
104. Greene KA, Wilde AH, Stulberg BN. Preoperative nutritional status of total joint patients. Relationship to postoperative wound complications. J Arthroplasty 1991;6(4):321-5.
105. Weber TR. A prospective analysis of factors influencing outcome after fundoplication. J Pediatr Surg 1995;30(7):1061-3; discussion 1063-4.
106. Vamvakas EC, Carven JH. Transfusion of white-cell-containing allogeneic blood components and postoperative wound infection: effect of confounding factors. Transfus Med 1998;8:29-36.
107. Vamvakas EC, Carven JH, Hibberd PL. Blood transfusion and infection after colorectal cancer surgery. Transfusion 1996;36:1000-8.
108. Jensen LS, Kissmeyer-Nielsen P, Wolff B, Qvist N. Randomised comparison of leucocyte-depleted versus buffy-coat-poor blood transfusion and complications after colorectal surgery. Lancet 1996;348:841-5.
109. Heiss MM, Mempel W, Jauch KW, Delanoff C, Mayer G, Mempel M, et al. Beneficial effect of autologous blood transfusion on infectious complications after colorectal cancer surgery. Lancet 1993;342:1328-33.
110. Lidgren L. Postoperative orthopaedic infections in patients with diabetes mellitus. Acta Orthop Scand 1973;44:149-51.
111. Gordon SM, Serkey JM, Barr C, Cosgrove D, Potts W. The relationship between glycosylated hemoglobin (HgA1c) levels and postoperative infections in patients undergoing primary coronary artery bypass surgery (CABG) [abstract]. Infect Control Hosp Epidemiol 1997; 18(No. 5, Part 2):29(58).
112. Zerr KJ, Furnary AP, Grunkemeier GL, Bookin S, Kanhere V, Starr A. Glucose control lowers the risk of wound infection in diabetics after open heart operations. Ann Thorac Surg 1997;63(2):356-61.
113. Terranova A. The effects of diabetes mellitus on wound healing. Plast Surg Nurs 1991;11(1):20-5.
114. Ziv Y, Church JM, Fazio VW, King TM, Lavery IC. Effect of systemic steroids on ileal pouch-anal anastomosis in patients with ulcerative colitis. Dis Colon Rectum 1996;39(5):504-8.

115. Pons VG, Denlinger SL, Guglielmo BJ, Octavio J, Flaherty J, Derish PA, et al. Ceftizoxime versus vancomycin and gentamicin in neurosurgical prophylaxis: a randomized, prospective, blinded clinical study. Neurosurgery 1993;33(3):416-22; discussion 422-3.
116. Brown IW Jr, Moor GF, Hummel BW, Marshall WG Jr, Collins JP. Toward further reducing wound infections in cardiac operations. Ann Thorac Surg 1996;62(6):1783-9.
117. Christou NV, Nohr CW, Meakins JL. Assessing operative site infection in surgical patients. Arch Surg 1987;122:165-9.
118. Hu SS, Fontaine F, Kelly B, Bradford DS. Nutritional depletion in staged spinal reconstructive surgery. The effect of total parenteral nutrition. Spine 1998;23:1401-5.
119. Schackert HK, Betzler M, Zimmermann GF, Decker R, Geelhaar H, Edler L, et al. The predictive role of delayed cutaneous hypersensitivity testing in postoperative complications. Surg Gynecol Obstet 1986;162:563-8.
120. Katelaris PH, Bennett GB, Smith RC. Prediction of postoperative complications by clinical and nutritional assessment. Aust N Z J Surg 1986;56:743-7.
121. Leite JF, Antunes CF, Monteiro JC, Pereira BT. Value of nutritional parameters in the prediction of postoperative complications in elective gastrointestinal surgery. Br J Surg 1987;74:426-9.
122. Mullen JL, Gertner MH, Buzby GP, Goodhart GL, Rosato EF. Implications of malnutrition in the surgical patient. Arch Surg 1979;114:121-5.
123. Buzby GP, Mullen JL, Matthews DC, Hobbs CL, Rosato EF. Prognostic nutritional index in gastrointestinal surgery. Am J Surg 1980;139:160-7.
124. Ellis LM, Copeland EM 3rd, Souba WW. Perioperative nutritional support. Surg Clin North Am 1991;71:493-507.
125. Haley RW, Culver DH, Morgan WM, White JW, Emori TG, Hooton TM. Identifying patients at high risk of surgical wound infection. A simple multivariate index of patient susceptibility and wound contamination. Am J Epidemiol 1985;121:206-15.
126. Culver DH, Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. Am J Med 1991;91(Suppl 3B):152S-7S.
127. Windsor JA, Hill GL. Weight loss with physiologic impairment. A basic indicator of surgical risk. Ann Surg 1988;207:290-6.
128. Campos AC, Meguid MM. A critical appraisal of the usefulness of perioperative nutritional support. Am J Clin Nutr 1992;55:117-30.
129. McPhee IB, Williams RP, Swanson CE. Factors influencing wound healing after surgery for metastatic disease of the spine. Spine 1998;23:726-33; discussion 732-3.
130. Mullen JL, Buzby GP, Matthews DC, Smale BF, Rosato EF. Reduction of operative morbidity and mortality by combined preoperative and postoperative nutritional support. Ann Surg 1980;192:604-13.
131. Windsor JA, Hill GL. Protein depletion and surgical risk. Aust N Z J Surg 1988;58:711-5.
132. Ulicny KS Jr, Hiratzka LF, Williams RB, Grunkemeier GL, Flege JB, Jr., Wright CB, et al. Sternotomy infection: poor prediction by acute phase response and delayed hypersensitivity. Ann Thorac Surg 1990;50:949-58.
133. Shukla HS, Rao RR, Banu N, Gupta RM, Yadav RC. Enteral hyperalimentation in malnourished surgical patients. Indian J Med Res 1984;80:339-46.
134. Moore EE, Jones TN. Benefits of immediate jejunostomy feeding after major abdominal trauma—a prospective, randomized study. J Trauma 1986;26:874-81.
135. Daly JM, Lieberman MD, Goldfine J, Shou J, Weintraub F, Rosato EF, et al. Enteral nutrition with supplemental arginine, RNA, and omega-3 fatty acids in patients after operation: immunologic, metabolic, and clinical outcome. Surgery 1992;112:56-67.
136. Daly JM, Weintraub FN, Shou J, Rosato EF, Lucia M. Enteral nutrition during multimodality therapy in upper gastrointestinal cancer patients. Ann Surg 1995;221:327-38.
137. Moore FA, Feliciano DV, Andrassy RJ, McArdle AH, Booth FV, Morgenstein-Wagner TB, et al. Early enteral feeding, compared with parenteral, reduces postoperative septic complications. The results of a meta-analysis. Ann Surg 1992;216:172-83.
138. Starker PM, Lasala PA, Askanazi J, Gump FE, Forse RA, Kinney JM. The response to TPN: a form of nutritional assessment. Ann Surg 1983;198:720-4.
139. Muller JM, Brenner U, Dienst C, Pichlmaier H. Preoperative parenteral feeding in patients with gastrointestinal carcinoma. Lancet 1982;1:68-71.
140. Holter AR, Fischer JE. The effects of perioperative hyperalimentation on complications in patients with carcinoma and weight loss. J Surg Res 1977;23:31-4.
141. Thompson BR, Julian TB, Stremple JF. Perioperative total parenteral nutrition in patients with gastrointestinal cancer. J Surg Res 1981;30:497-500.
142. Brennan MF, Pisters PW, Posner M, Quesada O, Shike M. A prospective randomized trial of total parenteral nutrition after major pancreatic resection for malignancy. Ann Surg 1994;220:436-41; discussion 441-4.
143. The Veterans Affairs Total Parental Nutrition Cooperative Study Group. Perioperative total parenteral nutrition in surgical patients. N Engl J Med 1991;325:525-32.
144. Starker PM, LaSala PA, Askanazi J, Todd G, Hensle TW, Kinney JM. The influence of preoperative total parenteral nutrition upon morbidity and mortality. Surg Gynecol Obstet 1986;162:569-74.
145. Senkal M, Mumme A, Eickhoff U, Geier B, Spath G, Wulfert D, et al. Early postoperative enteral immunonutrition: clinical outcome and cost-comparison analysis in surgical patients. Crit Care Med 1997;25:1489-96.
146. Heatley RV, Williams RH, Lewis MH. Pre-operative intravenous feeding—a controlled trial. Postgrad Med J 1979;55:541-5.
147. Muller JM, Keller HW, Brenner U, Walter M, Holzmuller W. Indications and effects of preoperative parenteral nutrition. World J Surg 1986;10:53-63.
148. Daly JM, Massar E, Giacco G, Frazier OH, Mountain CF, Dudrick SJ, et al. Parenteral nutrition in esophageal cancer patients. Ann Surg 1982;196:203-8.
149. Klein JD, Hey LA, Yu CS, Klein BB, Coufal FJ, Young EP, et al. Perioperative nutrition and postoperative complications in patients undergoing spinal surgery. Spine 1996;21:2676-82.
150. Garibaldi RA, Cushing D, Lerer T. Risk factors for postoperative infection. Am J Med 1991;91(Suppl 3B):158S-63S.
151. Lee JT. Operative complications and quality improvement. Am J Surg 1996;171:545-7.
152. Kluytmans JA, Mouton JW, VandenBergh MF, Manders MJ, Maat AP, et al. Reduction of surgical-site infections in cardiothoracic surgery by elimination of nasal carriage of *Staphylococcus aureus*. Infect Control Hosp Epidemiol 1996;17:780-5.
153. Boyce JM. Preventing staphylococcal infections by eradicating nasal carriage of *Staphylococcus aureus*: proceeding with caution. Infect Control Hosp Epidemiol 1996;17:775-9.
154. Blajchman MA. Allogeneic blood transfusions, immunomodulation, and postoperative bacterial infection: do we have the answers yet? Transfusion 1997;37:121-5.
155. Garibaldi RA. Prevention of intraoperative wound contamination with chlorhexidine shower and scrub. J Hosp Infect 1988;11(Suppl B):5-9.

156. Paulson DS. Efficacy evaluation of a 4% chlorhexidine gluconate as a full-body shower wash. Am J Infect Control 1993;21(4):205-9.
157. Hayek LJ, Emerson JM, Gardner AM. A placebo-controlled trial of the effect of two preoperative baths or showers with chlorhexidine detergent on postoperative wound infection rates. J Hosp Infect 1987;10:165-72.
158. Kaiser AB, Kernodle DS, Barg NL, Petracek MR. Influence of preoperative showers on staphylococcal skin colonization: a comparative trial of antiseptic skin cleansers. Ann Thorac Surg 1988;45:35-8.
159. Rotter ML, Larsen SO, Cooke EM, Dankert J, Daschner F, Greco D, et al. A comparison of the effects of preoperative whole-body bathing with detergent alone and with detergent containing chlorhexidine gluconate on the frequency of wound infections after clean surgery. The European Working Party on Control of Hospital Infections. J Hosp Infect 1988;11:310-20.
160. Leigh DA, Stronge JL, Marriner J, Sedgwick J. Total body bathing with 'Hibiscrub' (chlorhexidine) in surgical patients: a controlled trial. J Hosp Infect 1983;4:229-35.
161. Ayliffe GA, Noy MF, Babb JR, Davies JG, Jackson J. A comparison of pre-operative bathing with chlorhexidine-detergent and non-medicated soap in the prevention of wound infection. J Hosp Infect 1983;4:237-44.
162. Lynch W, Davey PG, Malek M, Byrne DJ, Napier A. Cost-effectiveness analysis of the use of chlorhexidine detergent in preoperative whole-body disinfection in wound infection prophylaxis. J Hosp Infect 1992;21:179-91.
163. Brady LM, Thomson M, Palmer MA, Harkness JL. Successful control of endemic MRSA in a cardiothoracic surgical unit. Med J Aust 1990;152:240-5.
164. Tuffnell DJ, Croton RS, Hemingway DM, Hartley MN, Wake PN, Garvey RJ. Methicillin-resistant Staphylococcus aureus; the role of antisepsis in the control of an outbreak. J Hosp Infect 1987;10:255-9.
165. Bartzokas CA, Paton JH, Gibson MF, Graham F, McLoughlin GA, Croton RS. Control and eradication of methicillin-resistant Staphylococcus aureus on a surgical unit. N Engl J Med 1984;311:1422-5.
166. Seropian R, Reynolds BM. Wound infections after preoperative depilatory versus razor preparation. Am J Surg 1971;121:251-4.
167. Hamilton HW, Hamilton KR, Lone FJ. Preoperative hair removal. Can J Surg 1977;20:269-71, 274-5.
168. Olson MM, MacCallum J, McQuarrie DG. Preoperative hair removal with clippers does not increase infection rate in clean surgical wounds. Surg Gynecol Obstet 1986;162:181-2.
169. Mehta G, Prakash B, Karmoker S. Computer assisted analysis of wound infection in neurosurgery. J Hosp Infect 1988;11:244-52.
170. Alexander JW, Fischer JE, Boyajian M, Palmquist J, Morris MJ. The influence of hair-removal methods on wound infections. Arch Surg 1983;118(3):347-52.
171. Masterson TM, Rodeheaver GT, Morgan RF, Edlich RF. Bacteriologic evaluation of electric clippers for surgical hair removal. Am J Surg 1984;148:301-2.
172. Sellick JA Jr., Stelmach M, Mylotte JM. Surveillance of surgical wound infections following open heart surgery. Infect Control Hosp Epidemiol 1991;12(10):591-6.
173. Ko W, Lazenby WD, Zelano JA, Isom W, Krieger KH. Effects of shaving methods and intraoperative irrigation on suppurative mediastinitis after bypass operations. Ann Thorac Surg 1992;53:301-5.
174. Moro ML, Carrieri MP, Tozzi AE, Lana S, Greco D. Risk factors for surgical wound infections in clean surgery: a multicenter study. Italian PRINOS Study Group. Ann Ital Chir 1996;67:13-9.
175. Winston KR. Hair and neurosurgery. Neurosurgery 1992;31(2):320-9.
176. Larson E. Guideline for use of topical antimicrobial agents. Am J Infect Control 1988;16:253-66.
177. Hardin WD, Nichols RL. Handwashing and patient skin preparation. In: Malangoni MA, ed. Critical Issues in Operating Room Management. Philadelphia: Lippincott-Raven; 1997. p. 133-49.
178. Ritter MA, French ML, Eitzen HE, Gioe TJ. The antimicrobial effectiveness of operative-site preparative agents: a microbiological and clinical study. J Bone Joint Surg Am 1980;62(5):826-8.
179. Mayhall CG. Surgical infections including burns. In: Wenzel RP, ed. Prevention and Control of Nosocomial Infections. 2nd ed. Baltimore: Williams & Wilkins; 1993. p. 614-64.
180. Committee on Control of Surgical Infections of the Committee on Pre- and Postoperative care, American College of Surgeons. Manual on Control of Infection in Surgical Patients. Philadelphia: J.B. Lippincott Co; 1984.
181. Hardin WD, Nichols RL. Aseptic technique in the operating room. In: Fry DE, ed. Surgical Infections. Boston: Little, Brown and Co; 1995. p. 109-18.
182. Lowbury EJ, Lilly HA. Use of 4 percent chlorhexidine detergent solution (Hibiscrub) and other methods of skin disinfection. Br Med J 1973;1:510-5.
183. Aly R, Maibach HI. Comparative antibacterial efficacy of a 2-minute surgical scrub with chlorhexidine gluconate, povidone-iodine, and chloroxylenol sponge-brushes. Am J Infect Control 1988;16:173-7.
184. Peterson AF, Rosenberg A, Alatary SD. Comparative evaluation of surgical scrub preparations. Surg Gynecol Obstet 1978;146:63-5.
185. Brown TR, Ehrlich CE, Stehman FB, Golichowski AM, Madura JA, Eitzen HE. A clinical evaluation of chlorhexidine gluconate spray as compared with iodophor scrub for preoperative skin preparation. Surg Gynecol Obstet 1984;158:363-6.
186. Lowbury EJ, Lilly HA. The effect of blood on disinfection of surgeons' hands. Br J Surg 1974;61:19-21.
187. Association of Operating Room Nurses. Recommended practices for skin preparation of patients. AORN J 1996;64(5):813-6.
188. Kutarski PW, Grundy HC. To dry or not to dry? An assessment of the possible degradation in efficiency of preoperative skin preparation caused by wiping skin dry. Ann R Coll Surg Engl 1993;75(3):181-5.
189. Gauthier DK, O'Fallon PT, Coppage D. Clean vs sterile surgical skin preparation kits. Cost, safety, effectiveness. AORN J 1993;58(3):486-95.
190. Hagen KS, Treston-Aurand J. A comparison of two skin preps used in cardiac surgical procedures. AORN J 1995;62(3):393-402.
191. Shirahatti RG, Joshi RM, Vishwanath YK, Shinkre N, Rao S, Sankpal JS, et al. Effect of pre-operative skin preparation on post-operative wound infection. J Postgrad Med 1993;39(3):134-6.
192. Larson EL, Butz AM, Gullette DL, Laughon BA. Alcohol for surgical scrubbing? Infect Control Hosp Epidemiol 1990;11(3):139-43.
193. Faoagali J, Fong J, George N, Mahoney P, O'Rouke V. Comparison of the immediate, residual, and cumulative antibacterial effects of Novaderm R*, Novascrub R*, Betadine Surgical Scrub, Hibiclens, and liquid soap. Am J Infect Control 1995;23(6):337-43.
194. Larson EL. APIC guideline for handwashing and hand antisepsis in health care settings. Am J Infect Control 1995;23:251-69.
195. Rubio PA. Septisol antiseptic foam: a sensible alternative to the conventional surgical scrub. Int Surg 1987;72(4):243-6.
196. Lowbury EJ, Lilly HA, Ayliffe GA. Preoperative disinfection of surgeons' hands: use of alcoholic solutions and effects of gloves on skin flora. Br Med J 1974;4:369-72.
197. Rotter ML. Hygienic hand disinfection. Infect Control 1984;5:18-22.
198. Ayliffe GA. Surgical scrub and skin disinfection. Infect Control 1984;5:23-7.
199. Lilly HA, Lowbury EJ, Wilkins MD, Zaggy A. Delayed antimicro-

bial effects of skin disinfection by alcohol. J Hyg (Lond) 1979;82:497-500.
200. Nichols RL, Smith JW, Garcia RY, Waterman RS, Holmes JW. Current practices of preoperative bowel preparation among North American colorectal surgeons. Clin Infect Dis 1997;24:609-19.
201. Wade JJ, Casewell MW. The evaluation of residual antimicrobial activity on hands and its clinical relevance. J Hosp Infect 1991;18(Suppl B):23-8.
202. Babb JR, Davies JG, Ayliffe GA. A test procedure for evaluating surgical hand disinfection. J Hosp Infect 1991;18(Suppl B):41-9.
203. Holloway PM, Platt JH, Reybrouck G, Lilly HA, Mehtar S, Drabu Y. A multi-centre evaluation of two chlorhexidine-containing formulations for surgical hand disinfection. J Hosp Infect 1990;16:151-9.
204. Kobayashi H. Evaluation of surgical scrubbing. J Hosp Infect 1991;18(Suppl B):29-34.
205. Nicoletti G, Boghossian V, Borland R. Hygienic hand disinfection: a comparative study with chlorhexidine detergents and soap. J Hosp Infect 1990;15:323-37.
206. Rotter ML, Koller W. Surgical hand disinfection: effect of sequential use of two chlorhexidine preparations. J Hosp Infect 1990;16:161-6.
207. O'Shaughnessy M, O'Malley VP, Corbett G, Given HF. Optimum duration of surgical scrub-time. Br J Surg 1991;78(6):685-6.
208. Hingst V, Juditzki I, Heeg P, Sonntag HG. Evaluation of the efficacy of surgical hand disinfection following a reduced application time of 3 instead of 5 min. J Hosp Infect 1992;20(2):79-86.
209. Wheelock SM, Lookinland S. Effect of surgical hand scrub time on subsequent bacterial growth. AORN J 1997;65:1087-92, 1094-8.
210. Deshmukh N, Kramer JW, Kjellberg SI. A comparison of 5-minute povidone-iodine scrub and 1-minute povidone-iodine scrub followed by alcohol foam. Mil Med 1998;163:145-7.
211. Masterson BJ. Cleansing the surgeon's hands. Scientific American Surgeon 1996;2:3-9.
212. Association of Operating Room Nurses. Standards, Recommended Practices, Guidelines. Denver: Association of Operating Room Nurses; 1999.
213. Pottinger J, Burns S, Manske C. Bacterial carriage by artificial versus natural nails. Am J Infect Control 1989;17:340-4.
214. Passaro DJ, Waring L, Armstrong R, Bolding F, Bouvier B, Rosenberg J, et al. Postoperative *Serratia marcescens* wound infections traced to an out-of-hospital source. J Infect Dis 1997; 175(4):992-5.
215. Baumgardner CA, Maragos CS, Walz J, Larson E. Effects of nail polish on microbial growth of fingernails. Dispelling sacred cows. AORN J 1993;58:84-8.
216. Jacobson G, Thiele JE, McCune JH, Farrell LD. Handwashing: ring-wearing and number of microorganisms. Nurs Res 1985;34:186-8.
217. Hoffman PN, Cooke EM, McCarville MR, Emmerson AM. Micro-organisms isolated from skin under wedding rings worn by hospital staff. Br Med J (Clin Res Ed) 1985;290:206-7.
218. Richet HM, Chidiac C, Prat A, Pol A, David M, Maccario M, et al. Analysis of risk factors for surgical wound infections following vascular surgery. Am J Med 1991;91(Suppl 3B):170S-172S.
219. Centers for Disease Control. Epidemic keratoconjunctivitis in an ophthalmology clinic—California. MMWR 1990;39:598-601.
220. Ford E, Nelson KE, Warren D. Epidemiology of epidemic keratoconjunctivitis. Epidemiol Rev 1987;9:244-61.
221. Birenbaum E, Linder N, Varsano N, Azar R, Kuint J, Spierer A, et al. Adenovirus type 8 conjunctivitis outbreak in a neonatal intensive care unit. Arch Dis Child 1993;68(5 Spec No):610-1.
222. Warren D, Nelson KE, Farrar JA, Hurwitz E, Hierholzer J, Ford E, et al. A large outbreak of epidemic keratoconjunctivitis: problems in controlling nosocomial spread. J Infect Dis 1989;160:938-43.
223. Jernigan JA, Lowry BS, Hayden FG, Kyger SA, Conway BP, Groschel DH, et al. Adenovirus type 8 epidemic keratoconjunctivitis in an eye clinic: risk factors and control. J Infect Dis 1993;167:1307-13.
224. Boyce JM. Should we vigorously try to contain and control methicillin-resistant *Staphylococcus aureus*? Infect Control Hosp Epidemiol 1991;12:46-54.
225. Boyce JM, Opal SM, Potter-Bynoe G, Medeiros AA. Spread of methicillin-resistant *Staphylococcus aureus* in a hospital after exposure to a health care worker with chronic sinusitis. Clin Infect Dis 1993;17:496-504.
226. Sheretz RJ, Reagan DR, Hampton KD, Robertson KL, Streed SA, Hoen HM, et al. A cloud adult: the *Staphylococcus aureus*-virus interaction revisited. Ann Intern Med 1996;124:539-47.
227. Belani A, Sherertz RJ, Sullivan ML, Russell BA, Reumen PD. Outbreak of staphylococcal infection in two hospital nurseries traced to a single nasal carrier. Infect Control 1986;7:487-90.
228. Kreiswirth BN, Kravitz GR, Schlievert PM, Novick RP. Nosocomial transmission of a strain of *Staphylococcus aureus* causing toxic shock syndrome. Ann Intern Med 1986;105:704-7.
229. Weber DJ, Rutala WA, Denny FW Jr. Management of healthcare workers with pharyngitis or suspected streptococcal infections. Infect Control Hosp Epidemiol 1996;17:753-61.
230. Viglionese A, Nottebart VF, Bodman HA, Platt R. Recurrent group A streptococcal carriage in a health care worker associated with widely separated nosocomial outbreaks. Am J Med 1991;91(3B):329S-33S.
231. Paul SM, Genese C, Spitalny K. Postoperative group A beta-hemolytic *streptococcus* outbreak with the pathogen traced to a member of a healthcare worker's household. Infect Control Hosp Epidemiol 1990;11:643-6.
232. Ridgway EJ, Allen KD. Clustering of group A streptococcal infections on a burns unit: important lessons in outbreak management. J Hosp Infect 1993;25:173-82.
233. Berkelman RL, Martin D, Graham DR, Mowry J, Freisem R, Weber JA, et al. Streptococcal wound infection caused by a vaginal carrier. JAMA 1982;247:2680-2.
234. Schaffner W, Lefkowitz LB Jr., Goodman JS, Koenig MG. Hospital outbreak of infections with group A streptococci traced to an asymptomatic anal carrier. N Engl J Med 1969;280:1224-5.
235. Richman DD, Breton SJ, Goldman DA. Scarlet fever and group A streptococcal surgical wound infection traced to an anal carrier. J Pediatr 1977;90:387-90.
236. Stromberg A, Schwan A, Cars O. Throat carrier rates of beta-hemolytic streptococci among healthy adults and children. Scand J Infect Dis 1988;20:411-7.
237. Stamm WE, Feeley JC, Facklam RR. Wound infection due to group A *streptococcus* traced to a vaginal carrier. J Infect Dis 1978;138:287-92.
238. Bolyard EA, Tablan OC, Williams WW, Pearson ML, Shapiro CN, Deitchman SD, et al. Guideline for infection control in healthcare personnel, 1998. Hospital Infection Control Practices Advisory Committee. Am J Infect Control 1998;26:289-354.
239. Nichols RL, Holmes JW. Prophylaxis in bowel surgery. Curr Clin Top Infect Dis 1995;15:76-96.
240. Nichols RL, Smith JW, Muzik AC, Love EJ, McSwain NE, Timberlake G, et al. Preventive antibiotic usage in traumatic thoracic injuries requiring closed tube thoracostomy. Chest 1994;106(5):1493-8.
241. Bullock R, van Dellen JR, Ketelbey W, Reinach SG. A double-blind placebocontrolled trial of perioperative prophylactic antibiotics for elective neurosurgery. J Neurosurg 1988;69(5):687-91.
242. Page CP, Bohnen JM, Fletcher JR, McManus AT, Solomkin JS, Wittmann DH. Antimicrobial prophylaxis for surgical wounds. Guidelines for clinical care. Arch Surg 1993;128(1):79-88.

243. McQueen M, Littlejohn A, Hughes SP. A comparison of systemic cefuroxime and cefuroxime loaded bone cement in the prevention of early infection after total joint replacement. Int Orthop 1987;11:241-3.
244. Henley MB, Jones RE, Wyatt RWB, Hofmann A, Cohen RL. Prophylaxis with cefamandole nafate in elective orthopedic surgery. Clin Orthop 1986;209:249-54.
245. Buckley R, Hughes GN, Snodgrass T, Huchcroft SA. Perioperative cefazolin prophylaxis in hip fracture surgery. Can J Surg 1990;33:122-7.
246. Boyd RJ, Burke JF, Colton T. A double-blind clinical trial of prophylactic antibiotic in hip fractures. J Bone Joint Surg [Am] 1973;55A:1251-8.
247. Bernard A, Pillet M, Goudet P, Viard H. Antibiotic prophylaxis in pulmonary surgery. A prospective randomized double-blind trial of flash cefuroxime versus forty-eight-hour cefuroxime. J Thorac Cardiovasc Surg 1994;107(3):896-900.
248. Platt R, Zucker JR, Zaleznik DF, Hopkins CC, Dellinger EP, Karchmer AW, et al. Perioperative antibiotic prophylaxis and wound infection following breast surgery. J Antimicrob Chemother 1993;31(Suppl B):43-8.
249. Rimoldi RL, Haye W. The use of antibiotics for wound prophylaxis in spinal surgery. Orthop Clin North Am 1996;27(1):47-52.
250. Bennion RS, Hiatt JR, Williams RA, Wilson SE. A randomized, prospective study of perioperative antimicrobial prophylaxis for vascular access surgery. J Cardiovasc Surg (Torino) 1985;26:270-4.
251. Kaiser AB, Petracek MR, Lea JW 4th, Kernodle DS, Roach AC, Alford WC Jr, et al. Efficacy of cefazolin, cefamandole, and gentamicin as prophylactic agents in cardiac surgery. Results of a prospective, randomized, double-blind trial in 1030 patients. Ann Surg 1987;206(6):791-7.
252. Miedzinski LJ, Callaghan JC, Fanning EA, Gelfand ET, Goldsand G, Modry D, et al. Antimicrobial prophylaxis for open heart operations. Ann Thorac Surg 1990;50:800-7.
253. Doebbeling BN, Pfaller MA, Kuhns KR, Massanari RM, Behrendt DM, Wenzel RP. Cardiovascular surgery prophylaxis. A randomized, controlled comparison of cefazolin and cefuroxime. J Thorac Cardiovasc Surg 1990;99:981-9.
254. Madsen MS, Neumann L, Andersen JA. Penicillin prophylaxis in complicated wounds of hands and feet: a randomized , double-blind trial. Injury 1996;27(4):275-8.
255. Burnett JW, Gustilo RB, Williams DN, Kind AC. Prophylactic antibiotics in hip fractures. A double-bind, prospective study. J Bone Joint Surg [Am]1980;62(3):457-62.
256. Nichols RL, Webb WR, Jones JW, Smith JW, LoCicero J 3rd. Efficacy of antibiotic prophylaxis in high risk gastroduodenal operations. Am J Surg 1982;143:94-8.
257. Lewis RT, Goodall RG, Marien B, Park M, Lloyd-Smith W, Wiegand FM. Efficacy and distribution of single-dose preoperative antibiotic prophylaxis in high-risk gastroduodenal surgery. Can J Surg 1991;34:117-22.
258. Young RF, Lawner PM. Perioperative antibiotic prophylaxis for prevention of postoperative neurosurgical infections. A randomized clinical trial. J Neurosurg 1987;66:701-5.
259. Djindjian M, Lepresle E, Homs JB. Antibiotic prophylaxis during prolonged clean neurosurgery. Results of a randomized double-blind study using oxacillin. J Neurosurg 1990;73:383-6.
260. Targarona EM, Garau J, Munoz-Ramos C, Roset F, Lite J, Matas E, et al. Single-dose antibiotic prophylaxis in patients at high risk for infection in biliary surgery: a prospective and randomized study comparing cefonicid with mezlocillin. Surgery 1990;107:327-34.
261. van Ek B, Dijkmans BA, van Dulken H, van Furth R. Antibiotic prophylaxis in craniotomy: a prospective double-blind placebo-controlled study. Scand J Infect Dis 1988;20:633-9.
262. Krige JE, Isaacs S, Stapleton GN, McNally J. Prospective, randomized study comparing amoxycillin-clavulanic acid and cefamandole for the prevention of wound infection in high-risk patients undergoing elective biliary surgery. J Hosp Infect 1992;22 (Suppl A):33-41.
263. Browder W, Smith JW, Vivoda LM, Nicholas RL. Nonperforative appendicitis: a continuing surgical dilemma. J Infect Dis 1989;159(6):1088-94.
264. Platt R. Guidelines for perioperative antibiotic prophylaxis. In: Abrutyn E, Goldmann DA, Scheckler WE, eds. Saunders infection control reference service. Philadelphia: W.B. Saunders Co; 1997. p. 229-34.
265. Sanderson PJ. Antimicrobial prophylaxis in surgery: microbiological factors. J Antimicrob Chemother 1993;31(Suppl B):1-9.
266. Anonymous. Antimicrobial prophylaxis in surgery. Med Lett Drugs Ther 1997;39(1012):97-102.
267. Scher KS. Studies on the duration of antibiotic administration for surgical prophylaxis. Am Surg 1997;63:59-62.
268. Nichols RL. Antibiotic prophylaxis in surgery. J Chemother 1989;1(3):170-8.
269. Ehrenkranz NJ. Antimicrobial prophylaxis in surgery: mechanisms, misconceptions, and mischief. Infect Control Hosp Epidemiol 1993;14(2):99-106.
270. Berkeley AS, Freedman KS, Ledger WJ, Orr JW, Benigno BB, Gordon SF, et al. Comparison of cefotetan and cefoxitin prophylaxis for abdominal and vaginal hysterectomy. Am J Obstet Gynecol 1988;158:706-9.
271. Ehrenkranz NJ, Blackwelder WC, Pfaff SJ, Poppe D, Yerg DE, Kaslow RA. Infections complicating low-risk cesarean sections in community hospitals: efficacy of antimicrobial prophylaxis. Am J Obstet Gynecol 1990;162(2):337-43.
272. Soper DE. Infections following cesarean section. Curr Opin Obstet Gynecol 1993;5(4):517-20.
273. Enkin M, Enkin E, Chalmers I, Hemminki E. Prophylactic antibiotics in association with caesarean section. In: Chalmers I, Enkin M, Keirse MJ, eds. Effective care in pregnancy and childbirth. London: Oxford University; 1989. p. 1246-69.
274. Allen JL, Rampon JF, Wheeless CR. Use of a prophylactic antibiotic in elective major gynecologic operations. Obstet Gynecol 1972;39:218-24.
275. The Multicenter Study Group. Single dose prophylaxis in patients undergoing vaginal hysterectomy: cefamandole versus cefotaxime. Am J Obstet Gynecol 1989;160:1198-201.
276. Roy S, Wilkins J, Galaif E, Azen C. Comparative efficacy and safety of cefmetazole or cefoxitin in the prevention of postoperative infection following vaginal and abdominal hysterectomy. J Antimicrob Chemother 1989;23(Suppl D):109-17.
277. Friese S, Willems FT, Loriaux SM, Meewis JM. Prophylaxis in gynaecological surgery: a prospective randomized comparison between single dose prophylaxis with amoxycillin/clavulanate and the combination of cefuroxime and metronidazole. J Antimicrob Chemother 1989;24(Suppl B):213-6.
278. Senior CC, Steigrad SJ. Are preoperative antibiotics helpful in abdominal hysterectomy? Am J Obstet Gynecol 1986;154:1004-8.
279. Hemsell DL, Martin JN Jr, Pastorek JG 2d, Nobles BJ, Hemsell PG, Helman N, et al. Single dose antimicrobial prophylaxis at abdominal hysterectomy. Cefamandole vs. cefotaxime. J Reprod Med 1988;33:939-44.
280. Hemsell DL, Hemsell PG, Heard ML, Nobles BJ. Preoperative cefoxitin prophylaxis for elective abdominal hysterectomy. Am J Obstet Gynecol 1985;153:225-6.
281. DiPiro JT, Cheung RP, Bowden TA Jr, Mansberger JA. Single dose systemic antibiotic prophylaxis of surgical wound infections. Am J Surg 1986;152:552-9.

282. Trilla A, Mensa J. Perioperative antibiotic prophylaxis. In: Wenzel RP, ed. Prevention and control of nosocomial infections. 2nd ed. Baltimore: Williams & Wilkins; 1993. p. 665-82.
283. Ehrenkranz NJ, Meakins JL. Surgical infections. In: Bennett JV, Brachman PS, eds. Hospital infections. 3rd ed. Boston: Little, Brown and Co; 1992. p. 685-710.
284. Nichols RL. Surgical antibiotic prophylaxis. Med Clin North Am 1995;79(3):509-22.
285. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. N Engl J Med 1992;326(5):281-6.
286. McDonald M, Grabsch E, Marshall C, Forbes A. Single- versus multiple-dose antimicrobial prophylaxis for major surgery: a systematic review. Aust N Z J Surg 1998;68:388-96.
287. Clarke JS, Condon RE, Bartlett JG, Gorbach SL, Nichols RL, Ochi S. Preoperative oral antibiotics reduce septic complications of colon operations: results of prospective, randomized, double-blind clinical study. Ann Surg 1977;186:251-9.
288. Condon RE, Bartlett JG, Greenlee H, Schulte WJ, Ochi S, Abbe R, et al. Efficacy of oral and systemic antibiotic prophylaxis in colorectal operations. Arch Surg 1983;118:496-502.
289. Bartlett JG, Condon RE, Gorbach SL, Clarke JS, Nichols RL, Ochi S. Veterans Administration Cooperative Study on bowel preparation for elective colorectal operation: impact of oral antibiotic regimen on colonic flora, wound irrigation cultures and bacteriology of septic complications. Ann Surg 1978; 188:249-54.
290. Da Costa A, Kirkorian G, Cucherat M, Delahaye F, Chevalier P, Cerisier A, et al. Antibiotic prophylaxis for permanent pacemaker implantation: a meta-analysis. Circulation 1998;97:1796-801.
291. Bumpous JM, Johnson JT. The infected wound and its management. Otolaryngol Clin North Am 1995;28(5):987-1001.
292. Hospital Infection Control Practices Advisory Committee. Recommendations for preventing the spread of vancomycin resistance. Infect Control Hosp Epidemiol 1995;16(2):105-13.
293. Forse RA, Karam B, MacLean LD, Christou NV. Antibiotic prophylaxis for surgery in morbidly obese patients. Surgery 1989;106:750-7.
294. Polk HC, Wilson MA. Systemic antibiotic prophylaxis in surgery. In: Fry DE, ed. Surgical infections. Boston: Little, Brown and Co; 1995. p. 127-33.
295. Ayliffe GA. Role of the environment of the operating suite in surgical wound infection. Rev Infect Dis 1991;13(Suppl 10):S800-4
296. Gryska PF, O'Dea AE. Postoperative streptococcal wound infection. The anatomy of an epidemic. JAMA 1970;213:1189-91.
297. McIntyre DM. An epidemic of *Streptococcus pyogenes* puerperal and postoperative sepsis with an unusual carrier site—the anus. Am J Obstet Gynecol 1968;101:308-14.
298. Lidwell OM. Clean air at operation and subsequent sepsis in the joint. Clin Orthop 1986;211:91-102.
299. American Institute of Architects. Guidelines for design and construction of hospital and health care facilities. Washington: American Instituite of Architects Press; 1996.
300. Nichols RL. The operating room. In: Bennett JV, Brachman PS, eds. Hospital infections. 3rd ed. Boston: Little, Brown and Co; 1992. p. 461-73.
301. Laufman H. The operating room. In: Bennett JV, Brachman PS, eds. Hospital Infections. 2nd ed. Boston: Little, Brown and Co; 1986. p. 315-23.
302. Sessler DI, McGuire J, Hynson J, Moayeri A, Heier T. Thermoregulatory vasoconstriction during isoflurane anesthesia minimally decreases cutaneous heat loss. Anesthesiology 1992;76:670-5.
303. Hambraeus A. Aerobiology in the operating room—a review. J Hosp Infect 1988;11(Suppl A):68-76
304. Babb JR, Lynam P, Ayliffe GA. Risk of airborne transmission in an operating theatre containing four ultraclean air units. J Hosp Infect 1995;31(3):159-68.
305. Charnley J. Post-operative infection after total hip replacement with special reference to contamination in the operating room. Internal Publication 38, Centre for Hip Surgery, Wrightington Hospital, Wigan, Lancs., UK; 1972.
306. Friberg B. Ultraclean laminar airflow ORs. AORN J 1998;67:841-51.
307. Lidwell OM, Elson RA, Lowbury EJ, Whyte W, Blowers R, Stanley SJ, et al. Ultraclean air and antibiotics for prevention of postoperative infection. A multicenter study of 8,052 joint replacemnet operations. Acta Orthop Scand 1987;58:4-13.
308. Nelson JP. The operating room environment and its influence on deep wound infection. J Bone Joint Surg 1976;1-11.
309. Whyte W. Infection control in hospital operating rooms. Cleanrooms 1993 Proceedings 1993;157-66.
310. Charnley J. A clean-air operating enclosure. Br J Surg 1964;51:202-5.
311. Lidwell OM, Lowbury EJ, Whyte W, Blowers R, Stanley SJ, Lowe D. Effect of ultraclean air in operating rooms on deep sepsis in the joint after total hip or knee replacement: a randomised study. Br Med J 1982;285:10-4.
312. Taylor GJ, Bannister GC, Leeming JP. Wound disinfection with ultraviolet radiation. J Hosp Infect 1995;30(2):85-93.
313. Bueno Cavanillas A, Rodriguez-Contreras R, Delgado Rodriguez M, Moreno Abril O, Gigosos R, Guillen Solvas J, et al. Preoperative stay as a risk factor for nosocomial infection. Eur J Epidemiol 1991;7(6):670-6.
314. Favero MS, Bond W. Sterilization, disinfection, and antisepsis in the hospital. In: Balows A, Hausler WJ Jr, Herrmann KL, Isenberg HD, Shadomy HJ, eds. Manual of clinical microbiology. 5th ed. Washington, DC: American Society of Microbiology; 1991. p. 183-200.
315. U.S. Department of Labor, Occupational Safety and Health Administration. Occupational exposure to bloodborne pathogens; final rule (29 CFR Part 1910.1030). Federal Register 1991;56: 64004-182.
316. Rudnick JR, Beck-Sague CM, Anderson RL, Schable B, Miller JM, Jarvis WR. Gram-negative bacteremia in open-heart-surgery patients traced to probable tap-water contamination of pressure-monitoring equipment. Infect Control Hosp Epidemiol 1996;17(5):281-5.
317. Centers for Disease Control. Postsurgical infections associated with nonsterile implantable devices. MMWR Morb Mortal Wkly Rep 1992;41(15):263.
318. Soto LE, Bobadilla M, Villalobos Y, Sifuentes J, Avelar J, Arrieta M, et al. Post-surgical nasal cellulitis outbreak due to *Mycobacterium chelonae*. J Hosp Infect 1991;19(2):99-106.
319. Favero MS, Manian FA. Is eliminating flash sterilization practical? Infect Control Hosp Epidemiol 1993;14(8):479-80.
320. American Society for Healthcare Central Service Personnel. Recommended practices for central service. Section one, continuous quality improvement. Chicago: American Hospital Association; 1993.
321. Association for the Advancement of Medical Instrumentation. Flash sterilization: steam sterilization of patient care items for immediate use (ANSI/AAMI ST37-1996). Arlington (VA): Association for the Advancement of Medical Instrumentation; 1996.
322. Rutala WA, Gergen MF, Weber DJ. Evaluation of a rapid readout biological indicator for flash sterilization with three biological indicators and three chemical indicators. Infect Control Hosp Epidemiol 1993;14(7):390-4.

323. Vesley D, Langholz AC, Rohlfing SR, Foltz WE. Fluorimetric detection of a *Bacillus stearothermophilus* spore-bound enzyme, alpha-D-glucosidase, for rapid indication of flash sterilization failure. Appl Environ Microbiol 1992;58:717-9.
324. Rutala WA, Jones SM, Weber DJ. Comparison of a rapid readout biological indicator for steam sterilization with four conventional biological indicators and five chemical indicators. Infect Control Hosp Epidemiol 1996;17:423-8.
325. Vesley D, Nellis MA, Allwood PB. Evaluation of a rapid readout biological indicator for 121 degrees C gravity and 132 degrees C vacuum-assisted steam sterilization cycles. Infect Control Hosp Epidemiol 1995;16:281-6.
326. Smith RF. What is the purpose of the scrub suit? [letter]. AORN J 1980;31(5):769
327. Dineen P. The role of impervious drapes and gowns preventing surgical infection. Clin Orthop 1973;96:210-2.
328. Ha'eri GB, Wiley AM. The efficacy of standard surgical face masks: an investigation using "tracer particles". Clin Orthop 1980;148:160-2.
329. Moylan JA, Fitzpatrick KT, Davenport KE. Reducing wound infections. Improved gown and drape barrier performance. Arch Surg 1987;122:152-7.
330. Moylan JA, Balish E, Chan J. Intraoperative bacterial transmission. Surg Forum 1974;25:29-30.
331. Copp G, Mailhot CB, Zalar M, Slezak L, Copp AJ. Covergowns and the control of operating room contamination. Nurs Res 1986;35:263-8.
332. Beck WC. The surgical mask: another 'sacred cow'? AORN J 1992;55:955-7.
333. Mitchell NJ, Hunt S. Surgical face masks in modern operating rooms—a costly and unnecessary ritual? J Hosp Infect 1991;18:239-42.
334. Tunevall TG, Jorbeck H. Influence of wearing masks on the density of airborne bacteria in the vicinity of the surgical wound. Eur J Surg 1992;158(5):263-6.
335. Tunevall TG. Postoperative wound infections and surgical face masks: a controlled study. World J Surg 1991;15:383-8.
336. Orr NW. Is a mask necessary in the operating theatre? Ann R Coll Surg Engl 1981;63(6):390-2.
337. Lee JT. Making surgical care better: hard work, small gains [editorial]. Infect Control Hosp Epidemiol 1997;18:6-8.
338. Jarvis WR, Bolyard EA, Bozzi CJ, Burwen DR, Dooley SW, Martin LS, et al. Respirators, recommendations, and regulations: the controversy surrounding protection of health care workers from tuberculosis. Ann Intern Med 1995;122:142-6.
339. Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health. Protect yourself against tuberculosis: a respiratory protection guide for health care workers (Publication No. 96-102). Cincinnati: Department of Health and Human Services (NIOSH); 1995.
340. Humphreys H, Marshall RJ, Ricketts VE, Russell AJ, Reeves DS. Theatre over-shoes do not reduce operating theatre floor bacterial counts. J Hosp Infect 1991;17:117-23.
341. Weightman NC, Banfield KR. Protective over-shoes are unnecessary in a day surgery unit. J Hosp Infect 1994;28:1-3.
342. Whyte W, Hambraeus A, Laurell G, Hoborn J. The relative importance of routes and sources of wound contamination during general surgery. I. Non-airborne. J Hosp Infect 1991;18(2):93-107.
343. Dodds RD, Guy PJ, Peacock AM, Duffy SR, Barker SG, Thomas MH. Surgical glove perforation. Br J Surg 1988;75(10):966-8.
344. Tokars JI, Culver DH, Mendelson MH, Sloan EP, Farber BF, Fligner DJ, et al. Skin and mucous membrane contacts with blood during surgical procedures: risk and prevention. Infect Control Hosp Epidemiol 1995;16:703-11.
345. Short LJ, Bell DM. Risk of occupational infection with blood-borne pathogens in operating and delivery room settings. Am J Infect Control 1993;21:343-50.
346. Garibaldi RA, Maglio S, Lerer T, Becker D, Lyons R. Comparison of nonwoven and woven gown and drape fabric to prevent intraoperative wound contamination and postoperative infection. Am J Surg 1986;152(5):505-9.
347. Muller W, Jiru P, Mach R, Polaschek F, Fasching W. The use of disposable draping materials in the operating room and its effect on the postoperative wound infection rate. Wein Klin Wochenschr 1989;101:837-42.
348. Smith JW, Nichols RL. Barrier efficiency of surgical gowns. Are we really protected from our patients' pathogens? Arch Surg 1991;126(6):756-63.
349. Artz CP, Conn JH, Howard HS. Protection of the surgical wound with a new plastic film. JAMA 1960;174(14):1865-8.
350. Chiu KY, Lau SK, Fung B, Ng KH, Chow SP. Plastic adhesive drapes and wound infection after hip fracture surgery. Aust N Z J Surg 1993;63(10):798-801.
351. American Society for Testing Materials. Standard Test Method for Resistance of Materials used in Protective Clothing to Penetration by Synthetic Blood. American Society for Testing Materials 1998;F1670-98.
352. American Society for Testing Materials. Standard Test Method for Resistance of Materials used in Protective Clothing to Penetration by Blood-borne Pathogens using Phi-X174 Bacteriophage Penetration as a Test System. American Society for Testing Materials 1997; F1671-976.
353. McCullough EA. Methods for determining the barrier efficacy of surgical gowns. Am J Infect Control 1993;21:368-74.
354. Lewis JA, Brown PL. Breaking the comfort barrier in impervious gowns. Surgical Services Management 1998;4(2):29-38.
355. Granzow JW, Smith JW, Nichols RL, Waterman RS, Muzik AC. Evaluation of the protective value of hospital gowns against blood strike-through and methicillin-resistant *Staphylococcus aureus* penetration. Am J Infect Control 1998;26:85-93.
356. Walter CW, Kundsin RB, Harding AL, Page LK. The infector on the surgical team. Clin Neurosurg 1966;14:361-79.
357. Payne RW. Severe outbreak of surgical sepsis due to *Staphylococcus aureus* of unusual type and origin. Br Med J 1967;4:17-20.
358. Centers for Disease Control. Hospital outbreak of streptococcal wound infection-Utah. MMWR Morb Mortal Wkly Rep 1976;25:141
359. Herwaldt LA, Pottinger J, Coffin SA. Nosocomial infections associated with anesthesia. In: Mayhall CG, ed. Hospital epidemiology and infection control. Baltimore: Williams & Wilkins; 1996. p. 655-75.
360. Bennett SN, McNeil MM, Bland LA, Arduino MJ, Villarino ME, Perrotta DM, et al. Postoperative infections traced to contamination of an intravenous anesthetic, propofol. N Engl J Med 1995;333:147-54.
361. Froggatt JW, Dwyer DM, Stephens MA. Hospital outbreak of hepatitis B in patients undergoing electroconvulsive therapy [abstract]. Program and Abstracts of the 31st Interscience Conference on Antimicrobial Agents and Chemotherapy, Chicago 1991;157:(347).
362. Centers for Disease Control. Postsurgical infections associated with an extrinsically contaminated intravenous anesthetic agent—California, Illinois, Maine, and Michigan, 1990. MMWR Morb Mortal Wkly Rep 1990;39:426-7,433.
363. Daily MJ, Dickey JB, Packo KH. Endogenous *Candida* endophthalmitis after intravenous anesthsia with propofol. Arch Ophthalmol 1991;109:1081-4.

364. Villarino ME, McNeill MM, Hall WN. Postsurgical infections associated with an extrinsically contaminated intravenous anesthetic agent [abstract]. Program and Abstracts of the 31st Interscience Conference on Antimicrobial Agents and Chemotherapy, Chicago 1991;156:(346).
365. American Association of Nurse Anesthetists. Infection control guide. Park Ridge (IL): American Association of Nurse Anesthetists; 1993.
366. American Society of Anesthesiologists. Recommendations for infection control for the practice of anesthesiology. Park Ridge (IL): American Society of Anesthesiologists; 1992.
367. Garner JS, Favero MS. CDC guideline for handwashing and hospital environmental control, 1985. Infect Control 1986;7:231-43.
368. Zacharias A, Habib RH. Delayed primary closure of deep sternal wound infections. Tex Heart Inst J 1996;23(3):211-6.
369. Smilanich RP, Bonnet I, Kirkpactrick JR. Contaminated wounds: the effect of initial management on outcome. Am Surg 1995;61(5):427-30.
370. Blomstedt GC. Infections in neurosurgery: a randomized comparison between silk and polyglycolic acid. Acta Neurochir (Wien) 1985;76:90-3.
371. Scher KS, Bernstein JM, Jones CW. Infectivity of vascular sutures. Am Surg 1985;51:577-9.
372. Durdey P, Bucknall TE. Assessment of sutures for use in colonic surgery: an experimental study. J R Soc Med 1984;77:472-7.
373. Chu CC, Williams DF. Effects of physical configuration and chemical structure of suture materials on bacterial adhesion. A possible link to wound infection. Am J Surg 1984;147:197-204.
374. Askew AR. A comparison of upper abdominal wound closure with monofilament nylon and polyglycolic acid. Aust N Z J Surg 1983;53:353-6.
375. Kapadia CR, Mann JB, McGeehan D, Jose Biglin JE, Waxman BP, Dudley HA. Behaviour of synthetic absorbable sutures with and without synergistic enteric infection. Eur Surg Res 1983;15:67-72.
376. Bucknall TE, Teare L, Ellis H. The choice of a suture to close abdominal incisions. Eur Surg Res 1983;15:59-66.
377. Bucknall TE. Factors influencing wound compications: a clinical and experimental study. Ann R Coll Surg Engl 1983;65:71-7.
378. Varma S, Lumb WV, Johnson LW, Ferguson HL. Further studies with polyglycolic acid (Dexon) and other sutures in infected experimental wounds. Am J Vet Res 1981;42:571-4.
379. Bucknall TE, Ellis H. Abdominal wound closure—a comparison of monofilament nylon and polyglycolic acid. Surgery 1981;89:672-7.
380. Dougherty SH, Simmons RL. The biology and practice of surgical drains. Part II. Curr Probl Surg 1992;29(9):635-730.
381. Cruse PJE. Wound infections: epidemiology and clinical characteristics in surgical infectious disease. In: Howard RJ, Simmons RL, eds. Surgical infectious diseases. 2nd ed. Norwalk (CT): Appleton and Lange; 1988. p. 319-29.
382. Drinkwater CJ, Neil MJ. Optimal timing of wound drain removal following total joint arthroplasty. J Arthroplasty 1995;10(2):185-9.
383. Tollofsrud SG, Gundersen Y, Andersen R. Perioperative hypothermia. Acta Anaesthesiol Scand 1984;28:511-5.
384. Sessler DI. Mild perioperative hypothermia. N Engl J Med 1997;336(24):1730-7.
385. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. N Engl J Med 1996;334(19):1209-15.
386. Hunt TK, Hopf HW. Wound healing and wound infection. What surgeons and anesthesiologists can do. Surg Clin North Am 1997;77:587-606.
387. Wenisch C, Narzt E, Sessler DI, Parschalk B, Lenhardt R, Kurz A, et al. Mild intraoperative hypothermia reduces production of reactive oxygen intermediates by polymorphonuclear leukocytes. Anesth Analg 1996;82:810-6.
388. Jonsson K, Hunt TK, Mathes SJ. Oxygen as an isolated variable influences resistance to infection. Ann Surg 1988;208:783-7.
389. Jonsson K, Jensen JA, Goodson WH 3d, West JM, Hunt TK. Assessment of perfusion in postoperative patients using tissue oxygen measurements. Br J Surg 1987;74:263-7.
390. Chang N, Goodson WH 3d, Gottrup F, Hunt TK. Direct measurement of wound and tissue oxygen tension in postoperative patients. Ann Surg 1983;197:470-8.
391. Knighton DR, Halliday B, Hunt TK. Oxygen as an antibiotic. The effect of inspired oxygen on infection. Arch Surg 1984;119:199-204.
392. Ikeda T, Tayefeh F, Sessler DI, Kurz A, Plattner O, Petschnigg B, et al. Local radiant heating increases subcutaneous oxygen tension. Am J Surg 1998;175:33-7.
393. DuMortier JJ. The resistance of healing wounds to infection. Surg Gynecol Obstet 1933;56:762-6.
394. Morain WD, Colen LB. Wound healing in diabetes mellitus. Clin Plast Surg 1990;17:493-501.
395. American Hospital Association. Infection control in the hospital. Chicago: American Hospital Association; 1979. p. 161-2.
396. Castle M, Ajemian E. Hospital infection control: principles and practice. New York: John Wiley & Sons; 1987. p. 114-6.
397. Centers for Disease Control. Isolation techniques for use in hospitals. Washington: Public Health Service Publication; 1970.
398. Kravitz M. Outpatient wound care. Crit Care Nurs Clin North Am 1996;8(2):217-33.
399. Condon RE, Schulte WJ, Malangoni MA, Anderson-Teschendorf MJ. Effectiveness of a surgical wound surveillance program. Arch Surg 1983;118:303-7.
400. Haley RW, Culver DH, White JW, Morgan WM, Emori TG, Munn VP. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. Am J Epidemiol 1985;121:182-205.
401. Lennard ES, Hargiss CO, Schoenknecht FD. Postoperative wound infection surveillance by use of bacterial contamination categories. Am J Infect Control 1985;13:147-53.
402. Olson MM, Lee JT Jr. Continuous, 10-year wound infection surveillance. Results, advantages, and unanswered questions. Arch Surg 1990;125:794-803.
403. Olson M, O'Connor MO, Schwartz ML. Surgical wound infections. A 5-year prospective study of 20,193 wounds at the Minneapolis VA Medical Center. Ann Surg 1984;199:253-9.
404. Weigelt JA. Risk of wound infections in trauma patients. Am J Surg 1985;150:782-4.
405. Weigelt JA, Haley RW, Seibert B. Factors which influence the risk of wound infection in trauma patients. J Trauma 1987;27(7):774-81.
406. Anonymous. New classification of physical status. Anesthesiology 1963;24:-111.
407. Owens WD. ASA physical status classification: a study on consistency of ratings. Anesthesiology 1978;49:239-43.
408. National Nosocomial Infections Surveillance System. Nosocomial infection rates for interhospital comparison: limitations and possible solutions. A report from the National Nosocomial Infections Surveillance (NNIS) System. Infect Control Hosp Epidemiol 1991;12:609-21.
409. Cardo DM, Falk PS, Mayhall CG. Validation of surgical wound surveillance. Infect Control Hosp Epidemiol 1993;14:211-5.
410. Horan T, Gaynes R, Culver D, National Nosocomial Infections Surveillance (NNIS) System, CDC. Development of predictive risk factors for nosocomial surgical site infections (SSI) [abstract]. Infect Control Hosp Epidemiol 1994;15(suppl):P46(M72).
411. Nichols RL, Smith JW, Klein DB, Trunkey DD, Cooper RH, Adinolfi MF, et al. Risk of infection after penetrating abdominal

trauma. N Engl J Med 1984;311:1065-70.
412. Nichols RL, Smith JW, Robertson GD, Muzik AC, Pearce P, Ozmen V, et al. Prospective alterations in therapy for penetrating abdominal trauma. Arch Surg 1993;128:55-64.
413. Horan TC, Culver DH, Gaynes RP, National Nosocomial Infections Surveillance (NNIS) System. Results of a multicenter study on risk factors for surgical site infections (SSI) following C-section (CSEC) [abstract]. Am J Infect Control 1996;24:84.
414. Roy MC, Herwaldt LA, Embrey R, Kuhns K, Wenzel RP, Perl TM. Does the NNIS risk index (NRI) predict which patients develop wound infection (SWI) after cardiothoracic (CT) surgery? [abstract]. 34th Interscience Conference on Antimicrobial Agents and Chemotherapy 1994; Orlando, FL:196.
415. Lee TB. Surveillance in acute care and nonacute care settings: current issues and concepts. Am J Infect Control 1997;25(2):121-4.
416. Lee JT. Wound infection surveillance. Infect Dis Clin North Am 1992;6(3):643-56.
417. Mead PB, Pories SE, Hall P, Vacek PM, Davis JH Jr, Gamelli RL. Decreasing the incidence of surgical wound infections. Validation of a surveillance-notification program. Arch Surg 1986;121:458-61.
418. Kerstein M, Flower M, Harkavy LM, Gross PA. Surveillance for postoperative wound infections: practical aspects. Am Surg 1978;44:210-4.
419. Poulsen KB, Jepsen OB. Failure to detect a general reduction of surgical wound infections in Danish hospitals. Dan Med Bull 1995;42:485-8.
420. Haley RW, Schaberg DR, McClish DK, Quade D, Crossley KB, Culver DH, et al. The accuracy of retrospective chart review in measuring nosocomial infection rates. Results of validation studies in pilot hospitals. Am J Epidemiol 1980;111(5):516-33.
421. Mulholland SG, Creed J, Dierauf LA, Bruun JN, Blakemore WS. Analysis and significance of nosocomial infection rates. Ann Surg 1974;180:827-30.
422. Wenzel RP, Osterman CA, Hunting KJ, Gwaltney JM Jr. Hospital-acquired infections. I. Surveillance in a university hospital. Am J Epidemiol 1976;103:251-60.
423. Simchen E, Shapiro JM, Michel J, Sacks T. Multivariate analysis of determinants of postoperative wound infection: a possible basis for intervention. Rev Infect Dis 1981;3(4):678-82.
424. Collier C, Miller DP, Borst M. Community hospital surgeon-specific infection rates. Infect Control 1987;8(6):249-54.
425. Ehrenkranz NJ, Shultz JM, Richter EL. Recorded criteria as a "gold standard" for sensitivity and specificity estimates of surveillance of nosocomial infection: a novel method to measure job performance. Infect Control Hosp Epidemiol 1995;16:697-702.
426. Hirschhorn LR, Currier JS, Platt R. Electronic surveillance of antibiotic exposure and coded discharge diagnoses as indicators of postoperative infection and other quality assurance measures. Infect Control Hosp Epidemiol 1993;14:21-8.
427. Simchen E, Wax Y, Pevsner B, Erdal M, Michel J, Modan M, et al. The Israeli Study of Surgical Infections (ISSI): I. Methods for developing a standardized surveillance system for a multicenter study of surgical infections. Infect Control Hosp Epidemiol 1988;9(6):232-40.
428. Burns SJ, Dippe SE. Postoperative wound infections detected during hospitalization and after discharge in a community hospital. Am J Infect Control 1982;10(2):60-5.
429. Laxson LB, Blaser MJ, Parkhurst SM. Surveillance for the detection of nosocomial infections and the potential for nosocomial outbreaks. Am J Infect Control 1984;12(6):318-24.
430. Mertens R, Jans B, Kurz X. A computerized nationwide network for nosocomial infection surveillance in Belgium. Infect Control Hosp Epidemiol 1994;15:171-9.
431. Ehrenkranz NJ. Surgical wound infection occurrence in clean operations; risk stratification for interhospital comparisons. Am J Med 1981;(70):909-14.
432. Baker C, Luce J, Chenoweth C, Friedman C. Comparison of case-finding methodologies for endometritis after cesarean section. Am J Infect Control 1995;23:27-33.
433. Gaynes RP, Horan TC. Surveillance of nosocomial infections. In: Mayhall CG, ed. Hospital Epidemiology and Infection Control. Baltimore:Williams & Wilkins;1996. p. 1017-31.
434. Horan TC, Emori TG. Definitions of key terms used in the NNIS system. Am J Infect Control 1997;25:112-6.
435. Polk BF, Tager IB, Shapiro M, Goren-White B, Goldstein P, Schoenbaum SC. Randomised clinical trial of perioperative cefazolin in preventing infection after hysterectomy. Lancet 1980; 1:437-41.
436. Salem RJ, Johnson J, Devitt P. Short term metronidazole therapy contrasted with povidone-iodine spray in the prevention of wound infection after appendicectomy. Br J Surg 1979;66:430-1.
437. Walsh AL, Roberts FJ, Bryce EA. Post-discharge surveillance of surgical wound infections [letter]. Can J Infect Control 1996;11(1):29.
438. Brown RB, Bradley S, Opitz E, Cipriani D, Pieczarka R, Sands M. Surgical wound infections documented after hospital discharge. Am J Infect Control 1987;15:54-8.
439. Rosendorf LL, Octavio J, Estes JP. Effect of methods of postdischarge wound infection surveillance on reported infection rates. Am J Infect Control 1983;11(6):226-9.
440. Ferraz EM, Ferraz AA, Coelho HS, Pereira Viana V, Sobral SM, Vasconcelos MD, et al. Postdischarge surveillance for nosocomial wound infection: does judicious monitoring find cases? Am J Infect Control 1995;23:290-4.
441. Andenaes K, Amland PF, Lingaas E, Abyholm F, Samdal F, Giercksky KE. A prospective, randomized surveillance study of postoperative wound infections after plastic surgery: a study of incidence and surveillance methods. Plast Reconstr Surg 1995;96(4):948-56.
442. Keeling NJ, Morgan MW. Inpatient and post-discharge wound infections in general surgery. Ann R Coll Surg Engl 1995;77:245-7.
443. Manian FA, Meyer L. Adjunctive use of monthly physician questionnaires for surveillance of surgical site infections after hospital discharge and in ambulatory surgical patients: report of a seven-year experience. Am J Infect Control 1997;25:390-4.
444. Manian FA, Meyer L. Comparison of patient telephone survey with traditional surveillance and monthly physician questionnaires in monitoring surgical wound infections. Infect Control Hosp Epidemiol 1993;14:216-8.
445. Reimer K, Gleed C, Nicolle LE. The impact of postdischarge infection on surgical wound infection rates. Infect Control 1987;8(6):237-40.
446. Sands K, Vineyard G, Platt R. Surgical site infections occuring after hospital discharge. J Infect Dis 1996;173:963-70.
447. Weigelt JA, Dryer D, Haley RW. The necessity and efficiency of wound surveillance after discharge. Arch Surg 1992;127:77-82.
448. Gravel-Tropper D, Oxley C, Memish Z, Garber GE. Underestimation of surgical site infection rates in obstetrics and gynecology. Am J Infect Control 1995;23:22-6.
449. Taylor S, Pearce P, McKenzie M, Taylor GD. Wound infection in total joint arthroplasty: effect of extended wound surveillance on wound infection rates. Can J Surg 1994;37(3):217-20.
450. Hulton LJ, Olmsted RN, Treston-Aurand J, Craig CP. Effect of postdischarge surveillance on rates of infectious complications after cesarean section. Am J Infect Control 1992;20:198-201.
451. Law DJ, Mishriki SF, Jeffery PJ. The importance of surveillance after discharge from hospital in the diagnosis of postoperative wound infection. Ann R Coll Surg Engl 1990;72:207-9.
452. Donovan IA, Ellis D, Gatehouse D, Little G, Grimley R, Armistead

S, et al. One-dose antibiotic prophylaxis against wound infection after appendicectomy: a randomized trial of clindamycin, cefazolin sodium and a placebo. Br J Surg 1979;66:193-6.
453. Bates T, Down RH, Houghton MC, Lloyd GJ. Topical ampicillin in the prevention of wound infection after appendicectomy. Br J Surg 1974;61:489-92.
454. Centers for Disease Control and Prevention. Evaluation of blunt suture needles in preventing percutaneous injuries among healthcare workers during gynecologic surgical procedures New York City, March 1993-June 1994. MMWR Morb Mortal Wkly Rep 1997;46(2):25-9.
455. Fanning C, Johnston BL, MacDonald S, LeFort-Jost S, Dockerty E. Postdischarge surgical site infection surveillance. Can J Infect Control 1995;10(3):75-9.
456. Holbrook KF, Nottebart VF, Hameed SR, Platt R. Automated postdischarge surveillance for postpartum and neonatal nosocomial infections. Am J Med 1991;91(Suppl 3B):125S-30S.
457. Zoutman D, Pearce P, McKenzie M, Taylor G. Surgical wound infections occuring in day surgery patients. Am J Infect Control 1990;18:277-82.
458. Seaman M, Lammers R. Inability of patients to self-diagnose wound infections. J Emerg Med 1991;9:215-9.
459. Goulbourne IA, Ruckley CV. Operations for hernia and varicose veins in a day-bed unit. Br Med J 1979;2:712-4.
460. Garvey JM, Buffenmyer C, Rycheck RR, Yee R, McVay J, Harger JH. Surveillance for postoperative infections in outpatient gynecologic surgery. Infect Control 1986;7(2):54-8.
461. Flanders E, Hinnant JR. Ambulatory surgery postoperative wound surveillance. Am J Infect Control 1990;18(5):336-9.
462. Gentry LO, Zeluff BJ, Cooley DA. Antibiotic prophylaxis in openheart surgery: a comparison of cefamandole, cefuroxime, and cefazolin. Ann Thorac Surg 1988;46:167-71.
463. Maki DG, Bohn MJ, Stolz SM, Kroncke GM, Archer CW, Myerowitz PD. Comparitive study of cefazolin, cefamandole, and vancomycin for surgical prophylaxis in cardiac and vascular operations. A double-blind randomized trial. J Thorac Cardiovasc Surg 1992;104:1423-34.
464. Haines SJ, Walters BC. Antibiotic prophylaxis for cerebrospinal fluid shunts: a metanalysis. Neurosurgery 1994;34(1):87-92.
465. Langley JM, LeBlanc JC, Drake J, Milner R. Efficacy of antimicrobial prophylaxis in placement of cerebrospinal fluid shunts: meta-analysis. Clin Infect Dis 1993;17:98-103.
466. Starr MB, Lally JM. Antimicrobial prophylaxis for ophthalmic surgery. Surv Ophthalmol 1995;39:485-501.
467. Gatell JM, Riba J, Lozano ML, Mana J, Ramon R, Garcia Sanmiguel J. Prophylactic cefamandole in orthopaedic surgery. J Bone Joint Surg Am 1984;66:1219-22.
468. Kent KC, Bartek S, Kuntz KM, Anninos E, Skillman JJ. Prospective study of wound complications in continuous infrainguinal incisions after lower limb arterial reconstruction: incidence, risk factors, and cost. Surgery 1996;119(4):378-83.
469. Wymenga AB, van Horn JR, Theeuwes A, Muytjens HL, Slooff TJ. Perioperative factors associated with septic arthritis after arthroplasty. Prospective multicenter study of 362 knee and 2,651 hip operations. Acta Orthop Scand 1992;63(6):665-71.
470. Stambough JL, Beringer D. Postoperative wound infections complicating adult spine surgery. J Spinal Disord 1992;5(3):277-85.
471. Trippel SB. Antibiotic-impregnated cement in total joint arthroplasty. J Bone Joint Surg Am 1986;68A:1297-302.
472. Nungu KS, Olerud C, Rehnberg L, Larsson S, Nordell P, Allvin I, et al. Prophylaxis with oral cefadroxil versus intravenous cefuroxime in trochanteric fracture surgery. A clinical multicentre study. Arch Orthop Trauma Surg 1995;114(6):303-7.
473. Norden CW. Antibiotic prophylaxis in orthopedic surgery. Rev Infect Dis 1991;13(Suppl 10):S842-6.
474. Aznar R, Mateu M, Miro JM, Gatell JM, Gimferrer JM, Aznar E, et al. Antibiotic prophylaxis in non-cardiac thoracic surgery: cefazolin versus placebo. Eur J Cardiothorac Surg 1991;5:515-8.
475. Cant PJ, Smyth S, Smart DO. Antibiotic prophylaxis is indicated for chest stab wounds requiring closed tube thoracostomy. Br J Surg 1993;80:464-6.
476. Pitt HA, Postier RG, MacGowan AW, Frank LW, Surmak AJ, Sitzman JV, et al. Prophylactic antibiotics in vascular surgery. Topical, systemic, or both? Ann Surg 1980;192:356-64.
477. Kaiser AB, Clayson KR, Mulherin JL Jr, Roach AC, Allen TR, Edwards WH, et al. Antibiotic prophylaxis in vascular surgery. Ann Surg 1978;188:283-9.
478. Bauer T, Vennits B, Holm B, Hahn-Pedersen J, Lysen D, Galatius H, et al. Antibiotic prophylaxis in acute nonperforated appendicitis. The Danish Multicenter Study Group II. Ann Surg 1989;209:307-11.
479. Skipper D, Corder AP, Karran SJ. A randomized prospective study to compare ceftizoxime with cephradine as single dose prophylaxis in elective cholecystectomy. J Hosp Infect 1991;17:303-6.
480. Kaufman Z, Engelberg M, Eliashiv A, Reiss R. Systemic prophylactic antibiotics in elective biliary surgery. Arch Surg 1984;119:1002-4.
481. Grant MD, Jones RC, Wilson SE, Bombeck CT, Flint LM, Jonasson O, et al. Single dose cephalosporin prophylaxis in high-risk patients undergoing surgical treatment of the biliary tract. Surg Gynecol Obstet 1992;174:347-54.
482. Lewis RT, Goodall RG, Marien B, Park M, Lloyd-Smith W, Wiegand FM. Biliary bacteria, antibiotic use, and wound infection in surgery of the gallbladder and common bile duct. Arch Surg 1987;122:44-7.
483. Saltzstein EC, Mercer LC, Peacock JB, Dougherty SH. Outpatient open cholecystectomy. Surg Gynecol Obstet 1992;174(3):173-5.
484. Meijer WS, Schmitz PI, Jeekel J. Meta-analysis of randomized, controlled clinical trials of antibiotic prophylaxis in biliary tract surgery. Br J Surg 1990;77:283-90.
485. Kaiser AB, Herrington JL Jr, Jacobs JK, Mulherin JL Jr, Roach AC, Sawyers JL. Cefoxitin versus erythromycin, neomycin, and cefazolin in colorectal operations. Importance of the duration of the surgical procedure. Ann Surg 1983;198:525-30.
486. Schoetz DJ Jr, Roberts PL, Murray JJ, Coller JA, Veidenheimer MC. Addition of parenteral cefoxitin to regimen of oral antibiotics for elective colorectal operations. A randomized prospective study. Ann Surg 1990;212:209-12.
487. Edmondson HT, Rissing JP. Prophylactic antibiotics in colon surgery. Arch Surg 1983;118:227-31.
488. Wapnick S, Guinto R, Reizis I, LeVeen HH. Reduction of postoperative infection in elective colon surgery with preoperative administration of kanamycin and erythromycin. Surgery 1979;85:317-21.
489. Washington JA 2d, Dearing WH, Judd ES, Elveback LR. Effect of preoperative antibiotic regimen on development of infection after intestinal surgery. Prospective, randomized, double-blind study. Ann Surg 1974;108:567-72.
490. Maki DG, Aughey DR. Comparative study of cefazolin, cefoxitin, and ceftizoxime for surgical prophylaxis in colo-rectal surgery. J Antimicrob Chemother 1982;10(Suppl C):281-7.
491. Rotman N, Hay JM, Lacaine F, Fagniez PL, The Association de Recherche en Chirurgie Cooperative Group. Prophylactic antibiotherapy in abdominal surgery. First- vs third-generation cephalosporins. Arch Surg 1989;124:323-7.
492. Lewis RT, Allan CM, Goodall RG, Marien B, Park M, Lloyd-Smith W, et al. Cefamandole in gastroduodenal surgery: a controlled, prospective, randomized, double-blind study. Can J Surg 1982;25(5):561-3.

493. McArdle CS, Morran CG, Anderson JR, Pettit L, Gemmell CG, Sleigh JD, et al. Oral ciprofloxacin as prophylaxis in gastroduodenal surgery. J Hosp Infect 1995;30(3):211-6.
494. Grandis JR, Vickers RM, Rihs JD, Yu VL, Johnson JT. Efficacy of topical amoxicillin plus clavulanate/ticarcillin plus clavulanate and clindamycin in contaminated head and neck surgery: effect of antibiotic spectra and duration of therapy. J Infect Dis 1994;170:729-32.
495. Johnson JT, Yu VL, Myers EN, Wagner RL. An assessment of the need for gram-negative bacterial coverage in antibiotic prophylaxis for oncological head and neck surgery. J Infect Dis 1987;155(2):331-3.
496. Elledge ES, Whiddon RG Jr, Fraker JT, Stambaugh KI. The effects of topical oral clindamycin antibiotic rinses on the bacterial content of saliva on healthy human subjects. Otolaryngol Head Neck Surg 1991;105:836-9.
497. Johnson JT, Yu VL, Myers EN, Wagner RL, Sigler BA. Cefazolin vs moxalactam? A double-blind randomzied trial of cephalosporins in head and neck surgery.Arch Otolaryngol Head Neck Surg 1986;112:151-3.

Selected Readings

Association of Operating Room Nurses. Standards, recommended practices, guidelines. Denver: Association of Operating Room Nurses; 1999.

Larson EL. APIC guideline for handwashing and hand antisepsis in health care settings. Am J Infect Control 1995;23:251-69.

Association of Operating Room Nurses. Recommended practices for skin preparation of patients. AORN J 1996;64:813-6.

Rutala WA. APIC guideline for selection and use of disinfectants. Am J Infect Control 1990;18:99-117.

Favero MS, Bond W. Sterilization, disinfection, and antisepsis in the hospital. In: Balows A, Haugler WJ Jr, Herrmann KL, Isenberg HD, Shadomy HJ, eds. Manual of clinical microbiology. 5th ed. Washington (DC): American Society for Microbiology; 1991. p. 183-200.

Association for the Advancement of Medical Instrumentation. Flash sterilization: steam sterilization of patient care items for immediate use (ANSI/AAMI ST37-1996). Arlington (VA): Association for the Advancement of Medical Instrumentation; 1996.

American Institute of Architects Committee. Guidelines for design and construction of hospital and health care facilities. Washington: American Instituite of Architects Press; 1996.

Association for the Advancement of Medical Instrumentation. Selection of surgical gowns and drapes in health care facilities (AAMI TIR No. 11-1994). Arlington (VA): Association for the Advancement of Medical Instrumentation; 1994.

Platt R. Guidelines for perioperative antibiotic prophylaxis. In: Abrutyn E, Goldmann DA, Scheckler WE, eds. Saunders infection control reference service. Philadelphia: W.B. Saunders Co; 1997. p. 229-34.

Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. N Engl J Med 1992;326:281-6.

Wong ES. Surgical site infections. In: Mayhall CG, ed. Hospital Epidemiology and Infection Control. Baltimore: Williams & Wilkins; 1996. p. 154-74.

Hochberg J, Murray GF. Principles of operative surgery: antisepsis, technique, sutures, and drains. In: Sabiston DC Jr, ed. Textbook of surgery: the biological basis of modern surgical practice. 15 ed. Philadelphia: W.B. Saunders Co; 1997. p. 253-63.

Roy MC. Surgical-site infections after coronary artery bypass graft surgery: discriminating site-specific risk factors to improve prevention efforts. Infect Control Hosp Epidemiol 1998;19:229-33.

Herwaldt LA, Pottinger J, Coffin SA. Nosocomial infections associated with anesthesia. In: Mayhall CG, ed. Hospital epidemiology and infection control. Baltimore: Williams & Wilkins; 1996. p. 655-75.

Gaynes RP, Horan TC. Surveillance of nosocomial infections. In: Mayhall CG, ed. Hospital epidemiology and infection control. Baltimore: Williams & Wilkins; 1996. p. 1017-31.

Roy MC, Perl TM. Basics of surgical-site infection surveillance. Infect Control Hosp Epidemiol 1997;18:659-68.

Lee JT. Surgical wound infections: surveillance for quality improvement. In: Fry DE, ed. Surgical Infections. Boston: Little, Brown and Co; 1995. p. 145-59.

Meier PA. Infection control issues in same-day surgery. In: Wenzel RP, ed. Prevention and control of nosocomial infections. 3rd ed. Baltimore: Williams & Wilkins; 1997. p. 261-82.

Burke JP. Infections of cardiac and vascular prostheses. In: Bennett JV, Brachman PS, eds. Hospital infections. 4th ed. Philadelphia: Lippincott-Raven; 1998. p. 599-612.

Lew DP, Waldvogel FA. Infections of skeletal prostheses. In: Bennett JV, Brachman PS, eds. Hospital Infections. 4th ed. Philadelphia: Lippincott-Raven; 1998. p. 613-20.

Nafziger DA, Saravolatz LD. Infection in implantable prosthetic devices. In: Wenzel RP, ed. Prevention and control of nosocomial infections. 3rd ed. Baltimore: Williams & Wilkins; 1997. p. 889-923.

CONTINUING EDUCATION EXAMINATION ON THE "GUIDELINE FOR PREVENTION OF SURGICAL SITE INFECTION, 1999"

The Centers for Disease Control and Prevention (CDC) is accredited as a provider of continuing education by the International Association for Continuing Education and Training (IACET) and the Accreditation Council for Continuing Medical Education (ACCME) and the American Nurses Credentialing Center's Commission on Accreditation. This learner-paced study package has been structured according to IACET's Criteria and Guidelines and ACCME's Essentials and Standards. The CDC designates this educational activity for a maximum of .15 continuing education units (CEUs), 1.5 category 1 credit (CME) toward the American Medical Association's Physician's Recognition Award, or 1.8 contact hours of continuing nurses education (CNE) credit.

INSTRUCTIONS FOR CREDIT

1. To receive credit, read the objectives and guideline, then complete and return the examination answer form either electronically *(http://www.cdc.gov/ncidod/hip/)* or by post to: SSI Guideline Evaluation Activity, Hospital Infections Program, Mailstop E69, Centers for Disease Control and Prevention, 1600 Clifton Road, NE, Atlanta, GA 30333.
2. Allow 45 days for processing the application and awarding credit. A certificate of completion will be mailed to you.
3. There is no fee for participating in this activity.
4. The deadline for applying for CEU, CME, or CNE for this learning activity is April 15, 2000.

OBJECTIVES

1. Describe the frequency of surgical site infections in hospitalized patients.
2. List the most frequently occurring pathogens associated with surgical site infections and list potential reservoirs of infection.
3. List three intrinsic factors associated with increased risk of surgical site infection.
4. Identify three preoperative practices that have been shown to reduce the risk of surgical site infection.
5. Identify three intraoperative practices that, although not proven, may reduce the risk of surgical site infection.
6. Define the criteria for surgical site infections used for surveillance purposes.
7. Describe inpatient, outpatient, and postdischarge methods of surgical site infection surveillance.
8. List three variables used to stratify the risks associated with development of surgical site infection.

EXAMINATION QUESTIONS (Circle the answer[s] on the answer form)

Part I.

1. SSIs are the most frequently occurring nosocomial infection among all hospitalized patients. T F
2. Most SSIs are confined to the incision. T F
3. When an SSI contributes to a patient's death, it is usually a serious infection involving organs or spaces accessed during the operation. T F
4. According to NNIS system data, the most frequently isolated pathogens in rank order from SSI are:
   a. *Escherichia coli*, *Klebsiella* spp., *Pseudomonas aeruginosa*, and coagulase-negative staphylococci
   b. *Staphylococcus aureus*, coagulase-negative staphylococci, *Enterococcus* spp., and *Escherichia coli*
   c. *Staphylococcus aureus*, *Enterococcus* spp., *Escherichia coli*, and *Pseudomonas aeruginosa*
   d. *Klebsiella* spp., *Pseudomonas aeruginosa*, *Staphylococcus aureus*, and coagulase-negative staphylococci
5. The risk of SSI is related to the interaction between the dose of bacterial contamination, the virulence of the organism, and the resistance of the host patient. T F
6. For most SSIs, which of the following is the primary source of pathogens
   a. Operating room air
   b. Surgical team members
   c. Contaminated instruments
   d. Patient's endogenous flora
7. Which of the following patient characteristics has been associated with increased SSI risk?
   a. Obesity (>20% ideal body weight)
   b. Coincident remote site infection
   c. Cigarette smoking
   d. All of the above
8. The association between SSI risk and receipt of steroids or immunosuppressive drugs is unresolved. T F
9. Preoperative antiseptic showering has been shown to reduce skin microbial colony counts and reduce SSI rates. T F
10. The surgical scrub must be performed for a duration of 10 minutes with an appropriate antiseptic. T F
11. Timing of antimicrobial prophylaxis should be such that an adequate bactericidal concentration of the drug is established in serum and tissues by the time the skin is incised. T F
12. Flash sterilization is acceptable for the routine reprocessing of surgical instruments that are in short supply. T F
13. Prophylactic antimicrobial agents should be extended for at least 72 hours postoperatively. T F
14. Operating rooms should be maintained at negative pressure with respect to corridors and adjacent areas. T F
15. An incision closed primarily should be protected with a sterile dressing for 24 to 48 hours postoperatively. T F
16. Surgical surveillance efforts should be targeted toward high-risk procedures. T F
17. Which of the following practices are identified as unresolved issues with respect to their potential for reducing SSI rates? (Select all that apply.)
   a. Providing coded surgeon-specific data to the infection control committee
   b. Covering a scrub suit when out of the operating suite
   c. Using tacky mats at the entrance to the operating suite
   d. Using ultraviolet radiation in the operating room
18. Which of the following practices is *not* considered good surgical technique?
   a. Gentle handling of tissues
   b. Maintaining effective hemostasis
   c. Placing of a drain through the main surgical incision
   d. Minimizing the amount of devitalized tissue
19. Infection control professionals should routinely assign the surgical wound classification. T F

ANSWER FORM

Continuing Education Examination on the "Guideline for Prevention of Surgical Site Infection, 1999." There is no fee for applying for CEU, CME or CNE for this learning activity; deadline for application is April 15, 2000.

Part I.

1.	T	F			6.	a	b	c	d	11.	T	F			16.	T	F		
2.	T	F			7.	a	b	c	d	12.	T	F			17.	a	b	c	d
3.	T	F			8.	T	F			13.	T	F			18.	a	b	c	d
4.	a	b	c	d	9.	T	F			14.	T	F			19.	T	F		
5.	T	F			10.	T	F			15.	T	F							

Part II.

The following questions will not be included in your examination score, but your answers are critical to help us evaluate who reads and implements the guideline.

20. Which of the following best describes your profession?
    - ❑ Physician
      Check one: ❑ Surgeon ❑ Anesthesiologist ❑ Infectious Disease ❑ OB/GYN ❑ Other
    - ❑ Infection Control Professional (includes Infection Control Nurse)
    - ❑ Nurse
      Check one: ❑ Operating Room Nurse ❑ Other
    - ❑ Operating Room Technician
    - ❑ Physician's Assistant
    - ❑ Pharmacist
    - ❑ Other (specify) _____
21. Are you responsible for managing surgical patients?
    ❑ Yes ❑ No
22. Are you responsible for developing policies for prevention and control of nosocomial surgical site infections?
    ❑ Yes ❑ No
23. Are you responsible for directing or performing surveillance of surgical site infections?
    ❑ Yes ❑ No
24. In which of the following settings do you perform the responsibilities identified in items 21 to 23 above? (Check all that apply)
    - ❑ Hospital-based (Check all that apply): ❑ Inpatient surgery ❑ Outpatient surgery
    - ❑ Free-standing surgery center
    - ❑ Home care services
25. How long did it take you to complete this learning activity?
    - ❑ Less than 90 minutes
    - ❑ 90 minutes
    - ❑ Greater than 90 minutes

Part III.

The following questions will not be included in your examination score, but will help us assess your perceptions of how well the learning objectives were met and how readable and easily understood the material was.

	1 Strongly Agree	2 Agree	3 Neither Agree nor Disagree	4 Disagree	5 Strongly Disagree
26. All learning objectives were relevant to the SSI Guideline.	1	2	3	4	5
27. I understood what the authors were trying to say.	1	2	3	4	5
28. I was able to interpret the tables and figure.	1	2	3	4	5
29. Overall, the presentation of the guideline enhanced my ability to read and understand it.	1	2	3	4	5

APPLICATION FOR CONTINUING EDUCATION CREDIT

Name: _____

Mailing address: _____

_____

Daytime phone number: _____

Type of credit: ❑ CEU ❑ CME ❑ CNE

Date of application: _____

Signature: _____

Return to: SSI Guideline Evaluation, Hospital Infections Program/CDC, Mailstop E69, 1600 Clifton Road, NE, Atlanta, GA 30333.

EXHIBIT DX20

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

AMERICAN JOURNAL OF EPIDEMIOLOGY
Vol 131, No 5
Printed in U S A.

RISK FACTORS FOR WOUND INFECTIONS AFTER TOTAL KNEE ARTHROPLASTY

STEVEN M. GORDON,[1] DAVID H. CULVER,[1] BRYAN P. SIMMONS,[2] AND WILLIAM R. JARVIS[1]

Gordon, S. M., D. H. Culver, B. P. Simmons, and W. R. Jarvis (CDC, Atlanta, GA 30333). Risk factors for wound infections after total knee arthroplasty. *Am J Epidemiology* 1990;131:905–16.

Wound infections are an infrequent but serious complication of total knee arthroplasty. Between January 1984 and November 1987, 20 of 243 (8.2%) patients at two affiliated hospitals developed surgical wound infections following 259 total knee arthroplasty procedures performed in clean-air operating rooms. Eighteen (90%) of the patients had deep infections; nine required removal of the prosthesis. A single surgeon (surgeon X) was associated with 18 of the procedures that had subsequent infection (risk ratio (RR) = 9.4, 95% confidence interval (CI) 2.2–39), and an investigation was carried out in an effort to explain the difference in infection rates between surgeon X and other surgeons. In a cohort study, stratified analyses identified a preoperative American Society of Anesthesiologists (ASA) physical status class ≥3, surgeon X, and early postoperative use of a continuous passive motion device as risk factors associated with surgical wound infection following total knee arthroplasty procedures. Logistic regression analyses identified being a patient operated on by surgeon X with an ASA class ≥3 as the only significant independent risk factor for total knee arthroplasty-associated surgical wound infections (RR = 9.3, 95% CI 2.8–31). The effect due to surgeon X could not be explained by receipt or timeliness of administration of antimicrobial prophylaxis, type of prosthesis inserted, duration of operation, postoperative use of continuous passive motion, or underlying etiology of joint disease. The authors conclude that surgical technique and patient's severity of illness were the primary determinants of surgical wound infection after total knee arthroplasty. This study demonstrates the complexity of epidemiologic investigation of surgical wound infections and the importance of considering patient severity of illness when interpreting surgeon-specific infection rates.

arthroplasty; cross infection; surgical wound infection

Surgical wound infection is an infrequent but serious complication of total knee arthroplasty. Despite the use of prophylactic antibiotics and laminar flow operating rooms, these surgical wound infections continue to occur (1–4). Approximately 3.5 million orthopedic procedures were performed in the United States in 1986; 91,000 (2.6

Received for publication September 1, 1988, and in final form October 30, 1989.

Abbreviations: ASA, American Society of Anesthesiologists; CI, confidence interval; RR, risk ratio.

[1] Hospital Infections Program, Center for Infectious Diseases, Centers for Disease Control, Atlanta, GA.

[2] 188 South Bellevue St., Suite 420, Memphis, TN 38104.

Reprint requests to Dr. William R. Jarvis, Hospital Infections Program, Center for Infectious Diseases, Centers for Disease Control, Building 1, Room 5044, Atlanta, GA 30333.

The authors acknowledge William Martone for reviewing the manuscript, Geraldine Jones and Linda Waller for technical assistance, and P. J. Hayes and Martha Trussler for assistance in the investigation.

percent) of these were total knee arthroplasty procedures and 201,000 (5.7 percent) were total or partial hip replacement procedures (5). Few data exist on the surgical wound infection rate associated with these procedures or the risk factors for infection. This report describes an investigation of surgical wound infections in patients following total knee arthroplasty and discusses the risk factors which we found associated with these infections.

Materials and Methods

Between January 1, 1984, and November 30, 1987, 20 patients developed surgical wound infections after undergoing total knee arthroplasty at two affiliated US institutions (hospitals A and B). Only one total knee arthroplasty-associated surgical wound infection had been identified at both hospitals between January 1 and December 31, 1983. No increase in the surgical wound infection rate was noted for patients undergoing hip replacement or other types of orthopedic surgical procedures at either hospital between January 1, 1984, and November 30, 1987. A preliminary investigation did not reveal a cause for the apparent increase in wound infections, and in December 1987, the investigation was intensified.

Hospital A is a 957-bed teaching hospital and hospital B is a 194-bed community hospital. Approximately 1,300 and 1,100 orthopedic procedures are performed annually at hospitals A and B, respectively. Eight orthopedic surgeons served on the staff at both hospitals. All total knee arthroplasty procedures were performed in one of the two clean-air laminar flow suites at each hospital.

A case was defined as any patient who developed a surgical wound infection after total knee arthroplasty at either hospital A or hospital B between January 1, 1984, and November 30, 1987. A surgical wound infection was defined by the presence of purulent drainage at the surgical site. The majority of patients with suspected surgical wound infections following total knee arthroplasty were examined by one of the investigators (B. P. S.). The date of onset of a surgical wound infection was defined as the day purulent drainage was first documented. Infections involving the prosthetic implant were classified as deep; all patients with deep surgical wound infections were readmitted for treatment at hospital A or B.

A retrospective cohort study for the period between January 1, 1984, and November 30, 1987, was performed by reviewing the medical records of all patients undergoing total knee arthroplasty procedures. Patients were identified by computerized line listings. There were 259 total knee arthroplasty procedures during the study period involving 243 patients. Sixteen patients had bilateral knee replacements during the study period; each knee operation was considered as an independent event because these patients were discharged after their first knee procedure and readmitted for their second knee operation. Reoperations for infectious complications done during the study period were not included in the study.

Medical records of the study patients were reviewed for the following information: age, sex, the etiology of underlying joint disease, prior knee surgery, the American Society of Anesthesiologists (ASA) classification of preoperative physical status, results of the preoperative hematocrit, use of steroids, the presence of diabetes, use of insulin, evidence of nosocomial infection, operating room, time of day of the operation, type of knee prosthesis implanted and type of fixation (cement or cementless), number of personnel in the operating room during the surgical procedure, the presence of assisting surgeons, intraoperative irrigations, the duration of postoperative wound drains, use of antimicrobial prophylaxis, the time from the first dose of antimicrobial prophylaxis to skin incision, duration of the operation (from skin incision to closure), duration of use of an intraoperative limb tourniquet, preoperative shaving, name of surgeon, use of the continuous

passive motor machine (including starting day and duration), duration of postoperative fever, duration of antimicrobial exposure or administration, the time from the total knee arthroplasty procedure to documentation of surgical wound infection, wound culture results, and the time from the total knee arthroplasty procedure to initial reoperation for cases.

Antimicrobial prophylaxis in surgery was confirmed by a nurse's or anesthesiologist's written notation of its time of administration. All prophylactic antimicrobials were administered intravenously. Timely use of antimicrobial prophylaxis was defined as a dose of a parenteral antimicrobial administered up to 60 minutes prior to skin incision. Assisted surgery was defined as the presence of more than one attending orthopedic surgeon at a procedure. Nosocomial infections were defined using Centers for Disease Control definitions (6). Fever was defined as an oral temperature greater than 37.8°C.

The continuous passive motion machine was used to provide passive range of motion to the knee joint in the postoperative period. Initially set at 30°, the range of flexion was increased 10–20° each day, based on patient tolerance. The continuous passive motion was used 20 hours per day and was discontinued once the patient achieved 90° of flexion or was discharged.

Two types of total condylar knee prosthetic devices were used in total knee arthroplasty procedures: the Insall/Bernstein (Zimmer, Inc., Warsaw, IN) and the Whiteside (Dow Corning Corporation, Arlington, TN). The Insall/Bernstein device was inserted with polyacrylic cement (which did not contain antimicrobials), while fixation of the Whiteside did not require cement. The type of prosthetic knee implanted was determined by the life expectancy of the patient, the underlying etiology of the diseased joint, prior joint surgery, and surgeon preference.

Preoperative shaving of the patients occurred either in the patient's room or in the preoperative holding area immediately prior to surgery; however, written documentation of shaving was provided in the medical record only for the former.

We interviewed operating room nurses at both hospitals and asked them to describe the operating room practices associated with total knee arthroplasty procedures. We also interviewed the nurse managers of the orthopedic floors, the preoperative shaving team personnel, and the personnel from the physical rehabilitation department, for detailed descriptions of their activities associated with patients undergoing total knee arthroplasty.

Hospitals A and B do not have orthopedic surgical house staff; therefore, all operations were performed by attending orthopedic surgeons. We interviewed several orthopedic surgeons and observed four total knee arthroplasty procedures performed by three different surgeons at hospitals A and B.

The identification and antimicrobial susceptibility testing of isolates obtained from aerobic and anaerobic cultures of purulent wound drainage from all patients were performed at hospital A by standard methods (7, 8).

Data collection and analysis were performed on a microcomputer using Epi-Info (Centers for Disease Control, Atlanta, GA) and PRODAS (Conceptual Software, Houston, TX). Pairs of incidence rates were compared using the one-tailed Fisher exact test (9), and approximate confidence intervals for the risk ratio were calculated using the Cornfield procedure (10). Equality among more than two incidence rates was tested using the usual chi-square test. Two-group comparisons of the distribution of continuous variables were made using the Wilcoxon rank-sum test (11). Multiple potential risk factors were investigated simultaneously by developing logistic regression models.

RESULTS

Epidemiologic investigation

Between January 1984 and November 1987, 243 patients underwent 259 total

knee arthroplasty procedures at hospitals A and B. Sixteen patients had bilateral knee procedures and were readmitted for their second knee operation. Of the 259 total knee arthroplasty procedures performed, 20 (7.7 percent) resulted in surgical wound infections (figure 1).

The median time interval from the date of the total knee arthroplasty procedure to the date of documentation of purulent drainage was 26 days (range, 13–200 days). Eighteen of the 20 infections were deep. Sixteen patients underwent 35 subsequent operations as a result of their surgical wound infections; the median time interval from the date of the total knee arthroplasty procedure to the date of first reoperation was 47 days (range, 13–510 days). The infected knee prosthesis was removed in nine patients; five underwent arthrodesis and four underwent subsequent implantation of a new prosthesis. All patients with surgical wound infections received antimicrobial prophylaxis, which consisted of a cephalosporin. Their mean duration of receipt of antimicrobials was 16.2 days (range, 4–67 days). No patient with a surgical wound infection died.

Surgical wound cultures were obtained a median of 26 days after surgery (range, 7 days–17 months). In 16 total knee arthroplasty-associated surgical wound infections, routine aerobic cultures of purulent wound drainage grew organisms; these included *Staphylococcus aureus* (five); *Staphylococcus epidermidis* (three); *Enterococcus* (two); *Peptococcus asaccharolyticus* (one); *Acinetobacter calcoaceticus* (one); Group A streptococcus (one); *Pseudomonas aeruginosa* (one); an anaerobic gram-positive coccus (not further identified) (one); and one mixed infection with an aerobic gram-positive coccus (not further identified) and *Enterobacter cloacae*. Two of the *S. aureus* isolates and one of the *S. epidermidis* isolates were methicillin resistant. The *P. asaccharolyticus* and the Group A streptococcus were sensitive to both penicillin and cephalothin.

To identify potential risk factors for total knee arthroplasty-associated surgical wound infections, we compared the surgical

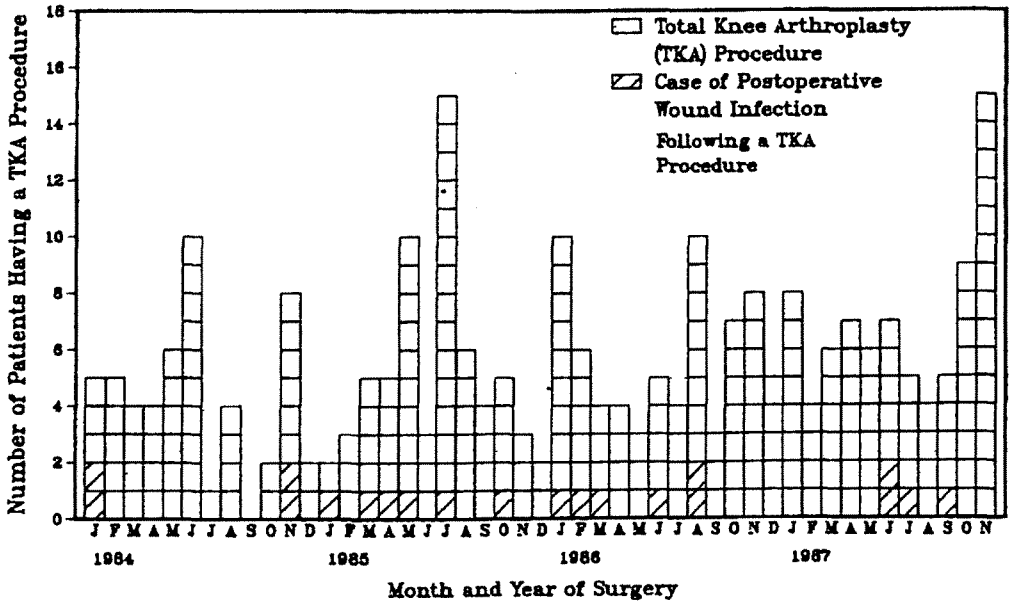


FIGURE 1. Distribution of total knee arthroplasty procedures and associated surgical wound infections, hospitals A and B, January 1984–November 1987.

wound infection incidence rates within levels of various categorical factors among cases and noncases (table 1). Eighteen of the 20 surgical wound infections occurred following total knee arthroplasty performed by surgeon X, who performed approximately half of all total knee arthroplasty procedures during the study period. Two other potential risk factors were identified in the univariate analysis to be significantly associated with wound infections after total knee arthroplasty: 1) those patients with an ASA class ≥3 had a significantly higher surgical wound infection rate than patients with an ASA class <3 (18/181 vs. 2/78; RR = 3.9, $p = 0.04$) and 2) those patients who began use of the continuous passive motion machine on the first postoperative day compared with patients who delayed use of the machine until after postoperative day 1 (11/83 vs. 3/121; $p = 0.003$). When the distributions of various continuous risk factors among cases and noncases were compared, only the number of postoperative days before initiating use of the continuous passive motion machine was associated with infection ($p = 0.02$; means, 2.6 days for cases and 4.5 days for noncases).

To look for clustering of cases by location, we stratified the epidemic curve of total knee arthroplasty-associated surgical wound infections by hospital and by surgeon. At both hospital A and hospital B, surgeon X's total knee arthroplasty-associated surgical wound infection rate was significantly higher than that of other surgeons (12/68 vs. 2/91 ($p = 0.0008$) and 6/59 vs. 0/41 ($p = 0.04$), respectively).

In an effort to explain the apparent association between surgeon X and surgical wound infection by the possible interaction of other confounding factors, we compared the distribution of various categorical and continuous factors among the 127 patients of surgeon X and the 132 patients of the seven other surgeons performing total knee arthroplasty procedures during the study period. We found the following significant differences: 1) a shorter duration for both operative and tourniquet times for patients of surgeon X than for other surgeons; 2) less overall use of continuous passive motion in surgeon X's patients, but earlier onset of continuous passive motion and longer duration when used; 3) more operations performed in the afternoon by surgeon X; 4) less frequent timely admin-

TABLE 1

Significant potential risk factors for surgical wound infections following total knee arthroplasty, hospitals A and B, January 1984–November 1987

Potential risk factor	Total no. of procedures	No. of procedures with SWI*	Incidence rate (%)	RR*	95% CI*	p
Surgeon						
Surgeon X	127	18	14.2	9.4	2.2–39	0.0001
Other surgeons	132	2	1.5			
ASA* class						
≥3	181	18	9.9	3.9	0.9–16	0.04
<3	78	2	2.6			
Continuous passive motion						
Not used	55	6	10.9			0.003
CPM* 1†	83	11	13.2			
CPM >1‡	121	3	2.5			

* SWI, surgical wound infections; RR, risk ratio; CI, confidence interval; ASA, American Society of Anesthesiologists; CPM, continuous passive motion.

† Patients receiving CPM on the first postoperative day.

‡ Patients receiving CPM after the first postoperative day.

istration of prophylactic antimicrobials for surgeon X's patients; 5) a greater proportion of surgeon X's patients with an ASA class ≥3; and 6) more assisted procedures for surgeon X (table 2).

Subsequent analyses focused on those factors which might explain all or part of the apparent association between surgeon X and the increased risk of total knee arthroplasty-associated surgical wound infections.

ASA physical status class

Of all the host factors we examined (preoperative length of stay, results of preoperative hematocrit, underlying etiology of joint disease, ASA class, use of steroids, the presence of diabetes, prior surgery, age, and sex), only ASA class was significantly associated with the risk of total knee arthroplasty-associated surgical wound infection.

We categorized the patients into two groups (ASA class ≥3 and ASA class <3) on the basis of the following: 1) The rates of surgical wound infection by ASA class indicated that those patients with an ASA class ≥3 were at greater risk of total knee arthroplasty-associated surgical wound infections than patients with an ASA class <3 (18/181 vs. 2/78; $p = 0.04$). 2) There was no significant difference in the incidence of surgical wound infections between ASA categories within each group (ASA class 1 vs. ASA class 2: 0/10 vs. 2/68, $p = 0.3$; ASA class 3 vs. ASA class 4: 17/171 vs. 1/10, $p = 0.5$). 3) Collapsing of ASA classes

TABLE 2

Potential risk factors for surgical wound infection after total knee arthroplasty, distributed among patients of surgeon X compared with patients of other surgeons, hospitals A and B, January 1984–November 1987

Potential risk factor	Surgeon X	Other surgeons	p
No. of operations	127	132	
Mean duration of operation (minutes)	95	110	<0.001
Mean duration of tourniquet application (minutes)	99	111	<0.001
Use of continuous passive motion	87 (69)*	117 (89)	<0.001
Continuous passive motion			
Not used	40 (31)	15 (11)	<0.001
CPM† 1‡	51 (40)	32 (24)	
CPM >1§	36 (28)	85 (64)	
Mean onset of continuous passive motion (days)	4.1	4.6	0.02
Mean duration of continuous passive motion (days)	12.4	10.6	0.02
Time of operation			
p.m.	85 (67)	55 (42)	<0.001
Timely administration of prophylactic antibiotic	18 (14)	38 (29)	0.003
ASA† class ≥3	98 (77)	83 (63)	0.009
Assisted surgery	28 (22)	14 (11)	0.006

* Numbers in parentheses, percentage.
† CPM, continuous passive motion; ASA, American Society of Anesthesiologists.
‡ Patients receiving CPM on the first postoperative day.
§ Patients receiving CPM after the first postoperative day.

into two groups is biologically plausible in that patients evaluated to be at greater risk of operative morbidity and mortality could be more susceptible to development of surgical wound infections.

Next, we compared the incidence of total knee arthroplasty-associated surgical wound infections between ASA groups for surgeon X and the other surgeons (table 3). For surgeon X, the surgical wound infection rate among patients with an ASA class ≥3 was significantly higher than among patients with an ASA class <3 (17/98 vs. 1/29; $p < 0.001$). Moreover, there was no significant difference between the surgical wound infection rate in patients of surgeon X with an ASA class <3 and patients of the other surgeons in either ASA group (1/29 vs. 1/83 vs. 1/49; $p = 0.74$). Hence, the increased risk of surgical wound infection associated with surgeon X was confined to patients with an ASA class ≥3.

Use of the continuous passive motion machine

Because the continuous passive motion machine was used in patient rehabilitation for 79 percent (204/259) of all procedures and the univariate analysis indicated that use and timing of continuous passive motion was associated with surgical wound infections, we investigated the interaction of continuous passive motion, ASA group, and surgeon to attempt to establish whether continuous passive motion use was truly a risk factor for surgical wound infection.

Among surgeon X's patients with an ASA class ≥3, the surgical wound infection rate was significantly higher among patients receiving continuous passive motion on the first postoperative day than among patients receiving continuous passive motion after the first postoperative day (11/41 vs. 1/24; $p = 0.02$). These data suggest the possibility that the timing of continuous passive motion machine use might explain some of the increase in total knee arthroplasty-associated surgical wound infection risk for surgeon X's patients with an ASA class ≥3. However, continuous passive motion alone could not explain the excess of surgical wound infections among patients of surgeon X with an ASA class ≥3, because the infection rate for patients not receiving continuous passive motion did not differ from the rate among patients

TABLE 3

Incidence rates of total knee arthroplasty-associated surgical wound infections, by patient ASA class, surgeon, and use of continuous passive motion, hospitals A and B, January 1984–November 1987*

ASA class and CPM*	Surgeon X		Other surgeons	
	No. of TKA* procedures	No. of SWI* (%)	No. of TKA procedures	No. of SWI (%)
≥3				
None	33	5 (15)	12	0 (0)
CPM 1†	41	11 (27)	22	0 (0)
CPM >1‡	24	1 (4)	49	1 (2)
	98	17 (17)	83	1 (1)
<3				
None	7	1 (14)	3	0 (0)
CPM 1	10	0 (0)	10	0 (0)
CPM >1	12	0 (0)	36	1 (3)
	29	1 (3)	49	1 (2)

* ASA, American Society of Anesthesiologists; CPM, continuous passive motion; TKA, total knee arthroplasty; SWI, surgical wound infections.

† Patients receiving CPM on the first postoperative day.

‡ Patients receiving CPM after the first postoperative day.

receiving continous passive motion on the first postoperative day (5/33 vs. 11/41; $p = 0.18$).

Antimicrobial prophylaxis

Surgical antimicrobial prophylaxis was used in 93 percent (240/259) of total knee arthroplasty procedures. Three cephalosporins accounted for 95 percent of all prophylactic antimicrobials used: cefazolin (46 percent; 111/240), cefonicid (31 percent; 74/240), and ceforanide (18 percent; 43/240). Surgeon X selected cefonicid most frequently (53 percent; 63/119), followed by ceforanide (27 percent) and cefazolin (15 percent). Other surgeons selected cefazolin most frequently (77 percent), followed by ceforanide and cefonicid (9 percent each).

Patients receiving antimicrobial prophylaxis before total knee arthroplasty were categorized into three groups: 1) patients receiving no antimicrobial prophylaxis; 2) patients receiving timely (i.e., ≤60 minutes prior to skin incision) antimicrobial prophylaxis, and 3) patients receiving untimely antimicrobial prophylaxis (>60 minutes prior to skin incision). There was no significant difference in rates of surgical wound infection among the three groups (0/19 vs. 3/56 vs. 16/184; $p = 0.3$), although the observed surgical wound infection rate was lower among patients receiving timely prophylaxis (5 percent) than among those receiving untimely prophylaxis (9 percent).

Within the cohort of surgeon X's patients with an ASA class ≥3, there was no significant difference in surgical wound infection rates when we compared timely prophylaxis with untimely or no prophylaxis (timely = 3/15 vs. untimely or none = 14/82; $p = 0.5$). These results suggest that administration of timely antimicrobial prophylaxis before a total knee arthroplasty procedure was neither an independent protective factor for total knee arthroplasty-associated surgical wound infection nor a modifying factor for surgical wound infection risk among patients of surgeon X with an ASA class ≥3.

Duration of operation and tourniquet times

Although the duration of an operation is often directly correlated with patient morbidity and mortality, we found no correlation with the duration of operative or tourniquet times and the risk of total knee arthroplasty-associated surgical wound infection.

Preoperative shaving

Preoperative shaving occurred on the night before surgery in 73 of the 259 (28 percent) total knee arthroplasty procedures. There was no association between preoperative shaving at this time and risk of total knee arthroplasty-associated surgical wound infections.

Multivariate analysis

The preceding analyses strongly suggest that the increased risk of wound infection after total knee arthroplasty was confined to patients of surgeon X with an ASA class ≥3 and that the increase in risk cannot be explained by type of prosthesis, timing or use of antimicrobial prophylaxis, or duration of operation or tourniquet time. The data did suggest that application of continuous passive motion on postoperative day 1 might have contributed in part to the increase in risk of surgical wound infection for patients of surgeon X. To evaluate the possibility that the joint influence of all of these factors, as well as other potential risk factors on which the patients of surgeon X differed from the patients of other surgeons, might explain the strong association with surgeon X, we fitted several logistic regression models to the data (table 4). In model 1, we included all of the potential risk factors other than surgeon X; only an ASA class ≥3 and receiving continuous passive motion on the first postoperative day were associated with surgical wound infection risk. Moreover, when the indicator variable for patients of surgeon X with an ASA class ≥3 was added to model 1, a highly significant improvement in the

TABLE 4

Multivariate analyses of risk factors for total knee arthroplasty-associated surgical wound infections, hospitals A and B, January 1984–November 1987

Potential risk factor	Regression coefficient	Standard error	p
Model 1			
ASA* class ≥3	1.32	0.77	0.04
CPM* 1†	0.87	0.49	0.04
Cemented prosthesis	0.63	0.67	0.17
Timely antimicrobial prophylaxis	−0.31	0.67	0.32
Duration of surgery (minutes)	−0 05	0.04	0.12
Tourniquet time (minutes)	0.06	0.05	0.10
p.m. time of operation	0 21	0.50	0.34
Intercept	−5.29		
Model 2			
ASA class ≥3	−0.78	1.24	0.26
CPM 1	0.76	0.49	0.06
Surgeon X and ASA class ≥3	2.74	1.04	0.004
Intercept	−3.89		
Model 3			
CPM 1	0.75	0.49	0.06
Surgeon X and ASA class ≥3	2.30	0.65	0.0002
Intercept	−4.22		
Model 4			
Surgeon X and ASA class ≥3	2.40	0.64	0.0001
Intercept	−3.96		

* ASA, American Society of Anesthesiologists; CPM, continuous passive motion.
† Use of CPM on the first postoperative day.

model was obtained ($p \approx 0.0001$), confirming that even the influence of all of the factors in model 1 does not explain the increase in risk associated with patients of surgeon X with an ASA class ≥3. Since model 1 suggests that having an ASA class ≥3 and receiving continuous passive motion on postoperative day 1 might have an independent effect on surgical wound infection risk, we included these two factors and the indicator for the combination of surgeon X and ASA class ≥3 in model 2. As expected, the lack of statistical significance of the term ASA class ≥3 in model 2 indicates that it is not an independent risk factor. Eliminating this term from model 2 yields model 3, and also eliminating the marginally significant continuous passive motion term yields model 4. The relative size of the regression coefficients for the term surgeon X and ASA class ≥3 in models 3 and 4 (2.30 vs. 2.40) indicate the possible contribution of continuous passive motion use on postoperative day 1 to the increase in surgical wound infection risk among patients of surgeon X. From model 4, the estimated ratio of surgical wound infection risk among patients of surgeon X with an ASA class ≥3, compared with all other patients, is 9.3 (95 percent CI 2.8–31).

DISCUSSION

This investigation of total knee arthroplasty-associated surgical wound infections emphasizes the complexity of investigating clusters of infections associated with surgery and the importance of careful analysis if the interpretation of differences in infection rates among surgeons is to be mean-

ingful. An initial comparison of surgeon-specific infection rates for 259 consecutive total knee arthroplasty procedures identified one surgeon (surgeon X) with a significantly higher infection rate. Univariate analyses identified several potential risk factors associated with total knee arthroplasty-associated surgical wound infections. Stratified analyses indicated that the increased risk associated with surgeon X was confined to patients with an ASA class ≥3 and a possible contribution to risk with continuous passive motion use. A comparison of patients of surgeon X with the patients of other surgeons revealed differences in distribution on several potential risk factors. Before a conclusion could be drawn regarding surgeon X, it was essential to rule out the possibility that a combination of these factors might account for the increased surgical wound infection risk experienced by some of his patients. Logistic regression analyses provided such evidence and enabled us to conclude that severity of illness and surgical technique were the primary determinants for total knee arthroplasty-associated wound infection.

Routine surveillance of surgeon-specific attack rates with confidential reporting to individual surgeons has been suggested as a means of decreasing surgical wound infection rates. Hospitals in which surgeon-specific infection rates were calculated had lower surgical wound infection rates (12). Subsequent investigators have reported a decline in surgical wound infection incidence rates, especially in the "clean" surgery categories, after surgeon-specific wound infection rates were introduced (13–17). However, the comparison of surgeon-specific attack rates without careful consideration of other potential risk factors, including severity of illness, can be misleading (18, 19). A comparison of surgeon-specific infection rates in this study was appropriate because 1) only infection rates for a specific procedure, total knee arthroplasty, were examined; 2) the wound class for all procedures was the same (class I, nonemergency); 3) the infection rates were compared among surgeons operating at the same institutions in which the anesthesia staff, surgical team, quality of the operating room facilities, and levels of asepsis appeared to be similar; 4) the infection rate was stratified by a measure of severity of illness; and 5) extensive data analysis revealed no significant risk factors among the patient characteristics found to differ between surgeon X and the other surgeons.

There were several limitations in our investigation that may have influenced our findings. First, quantitative and unbiased methods of assessing surgical procedures which include perioperative preparation, intraoperative technique, and postoperative care have not been developed. We attempted to identify any surgical practices or techniques specific to surgeon X which may have explained part or all of his higher rate of total knee arthroplasty-associated surgical wound infections in patients with an ASA class ≥3. Although we observed several total knee arthroplasty procedures, we could not assess every aspect of surgical technique, and other possible risk factors could not be evaluated retrospectively (e.g., the number of intraoperative glove changes, the amount of conversation and movement of personnel around the surgical field, the precision of the bone cuts and fit of the prosthetic implant, etc.). The duration of operation and tourniquet times, indirect measures of total knee arthroplasty operative technique that we could quantify, had no apparent association with surgical wound infection. Second, we were dependent on hospital medical records, so that data not documented in these records could not be evaluated.

We were able to assess the influence of several potential risk factors thought to influence total knee arthroplasty-associated surgical wound infection. Continuous passive motion following total knee arthroplasty has been reported to achieve range of motion in the knee joint more quickly and with less discomfort (20–22).

Use of continuous passive motion may also increase the amount of postoperative drainage from the wound site, possibly promoting wound breakdown, skin necrosis, and subsequent infection (22). We found neither use of continuous passive motion nor the timing of first use of continuous passive motion to be a strong risk factor for total knee arthroplasty-associated surgical wound infection, although initiation of continuous passive motion on the first postoperative day may have contributed slightly to increased risk.

Prophylactic antimicrobials are used frequently in the surgical setting (23). In our investigation, antimicrobial prophylaxis was used for almost all total knee arthroplasty procedures. However, timely administration of prophylactic antimicrobials occurred less than 25 percent of the time. Our data showed that administration of prophylactic antimicrobials, whether timely or not, did not reduce the risk of total knee arthroplasty-associated surgical wound infections. These findings are comparable with the results of a study of total hip replacements which found that 5 days of cefazolin at the time of surgery did not prevent either early or late surgical wound infections in patients operated on in laminar flow clean-air rooms (24, 25).

Quantitative and unbiased methods of assessing severity of illness are important in all studies examining patient morbidity or mortality. Although severity-of-illness indices have been developed for mortality (e.g., the Physiologic Stability Index (PSI) (26), the Therapeutic Intervention Scoring System (TISS) (27), Acute Physiology and Chronic Health Evaluation (APACHE II) (28), and the Computerized Severity Index (CSI) (29)), few nosocomial infection risk indices exist. The Study on the Efficacy of Nosocomial Infection Control (SENIC) reported a simple additive index involving three risk factors which predicted surgical wound infection risk in a general surgery population (30). This index predicted patients at risk of surgical wound infection with greater accuracy than the traditional wound classification system, presumably because it incorporated information on wound contamination, duration of procedure, and patient severity of illness.

Our investigation differed from the SENIC study in that we were looking for risk factors associated with a specific orthopedic procedure with clean wounds. Patients were stratified by anesthesia risk categories and other host factors. ASA class as a severity-of-illness measure for risk of surgical wound infection has the following advantages: 1) assignment of an ASA class occurs prior to the time of surgery; 2) data are gathered by a physician; 3) criterion sets for determining each category of severity which were developed by a consensus of medical experts have been published; and 4) the system is in place at all hospitals. The major disadvantage is that no attempt has been made to quantify severity distinctions beyond the 1–5 classification.

We conclude that careful analysis is required in reporting surgeon-specific infection rates. The surgeon-specific infection rates for specific surgical procedures should be adjusted for patient severity of illness, although which index of "patient susceptibility" is most appropriate for each type of surgical procedure requires further investigation.

References

1. Salvati EA, Robinson RP, Zeno SM, et al. Infection rates after 3,175 total hip and total knee replacements performed with and without a horizontal unidirectional filtered air-flow system. J Bone Joint Surg [Am] 1982;64A:525–35.
2. Poss R, Thornshill TS, Ewald FC, et al. Factors influencing the incidence and outcome of infectious following total joint arthroplasty. Clin Orthop 1984;182:117–26.
3. Marotte JH, Lord GA, Blanchard JP, et al. Infection rate in total hip arthroplasty as a function of air cleanliness and antibiotic prophylaxis. J Arthroplasty 1987,2:77–82.
4. Grogan TJ, Dorey F, Rollins J, et al. Deep sepsis following total knee arthroplasty: ten-year experience at the University of California at Los Angeles Medical Center. J Bone Joint Surg [Am] 1986;68A:226–34.
5. US Public Health Service. Detailed diagnosis procedures for patients discharged from short-stay

hospitals, United States, 1986. (National Health Survey, Series 13, no. 95). (US PHS publication no. (PHS)88-1756). Hyattsville, MD: US Public Health Service, 1988:203.
6. Garner JS, Jarvis WR, Emori TG, et al. CDC definitions for nosocomial infections, 1988. Am J Infect Control 1988;16:128–40.
7. Ederer MG, Lund ME. Biochemical test procedures, reagents, stains, staining methods, and media. In: Balows A, Hausler W, eds. Diagnostic procedures for bacterial, mycotic, and parasitic infections. 6th ed. Washington, DC: American Public Health Association, 1981:791–838.
8. Performance standards for antimicrobial disk susceptibility test. Villanova, PA: National Committee for Clinical Laboratory Standards, 1983:3.
9. Rosner BA. Fundamentals of biostatistics. Boston: Duxbury Press, 1982:308
10. Fleiss JL. Statistical methods for rates and proportions. New York: John Wiley and Sons, 1981: 71–5.
11. Siegel S. Nonparametric statistics for the behavioral sciences. New York: McGraw-Hill, 1956:184.
12. Haley RW, Culver DH, White JW, et al. The efficacy of infection surveillance and control programs in preventing nosocomial infections in US hospitals. Am J Epidemiol 1985;121:182–205.
13. Cruse PJE, Foord R. The epidemiology of wound infection: a ten-year prospective study of 62,939 wounds. Surg Clin North Am 1980;60:27–40.
14. Condon RE, Schulte WJ, Malangoni MA, et al. Effectiveness of a surgical wound surveillance program. Arch Surg 1983;118:303–7.
15. Gil-Egea MJ, Pi-Sunyer MT, Verdaguer A, et al. Surgical wound infections: prospective study of 4,468 clean wounds. Infect Control 1987;8:277–80.
16. Olson M, O'Connor M, Schwartz ML: Surgical wound infections: a prospective study of 20,193 wounds at the Minneapolis VA medical center. Arch Surg 1984;199:253–9.
17. Mead PB, Ponies SE, Hall P. Decreasing the incidence of surgical wound infections. Arch Surg 1986;121:458–61.
18. Scheckler WE. Surgeon-specific wound infection rates: a potentially dangerous and misleading strategy Infect Control 1988;9:145–6.
19. Scher KS. Importance of severity of illness in outcome assessment. (Letter). N Engl J Med 1987; 317:171
20 Romness DW, Rand JA. The role of continuous passive motion following total knee arthroplasty. Clin Orthop 1988;226:34–7.
21. Salter RB, Clements ND, Ogilvie-Harris D, et al. The healing of articular tissues through continuous passive motion: essence of the first 10 years of experimental investigations. (Abstract). J Bone Joint Surg [Br] 1982;64B:640.
22. Couts RD, Sharp DN, Borden LS, et al. The effect of continuous passive motion on total knee rehabilitation. Orthop Trans 1983;7:535–6.
23. Kaiser AB. Antimicrobial prophylaxis in surgery. N Engl J Med 1986;315:1129–31.
24. Hill C, Mazas F, Flamannt R, et al. Prophylactic cefazolin versus placebo in total hip replacement: report of a multicentre double blind randomised trial. Lancet 1981;1:795–7.
25. Doyon F, Evrard J, Mazas F, et al. Long-term results of prophylactic cefazolin versus placebo in total hip replacement. (Letter). Lancet 1987;1:860.
26. Pollack MM, Ruttimann UE, Getson PR, et al. Accurate prediction of the outcome of pediatric intensive care: a new quantitative method. N Engl J Med 1987;316:134–9.
27. Cullen DJ, Civetta JM, Briggs BA, et al. Therapeutic Intervention Scoring System: a method for quantitative comparison of patient care. Crit. Care Med 1974;2:57–61.
28. Knaus WA, Draper EA, Wagner DP, et al. APACHE II: a severity of disease classification system. Crit Care Med 1985;13:818–29.
29. Horn SD, Horn RA. The computerized severity index: a new tool for case-mix management. J Med Syst 1986;10:73–8.
30. Haley RW, Culver DH, Morgan WM, et al. Identifying patients at high risk of surgical wound infection: a simple multivariate index of patient susceptibility and wound contamination. Am J Epidemiol 1985;121:206–15.

EXHIBIT DX21

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

UNITED STATES DISTRICT COURT

DISTRICT OF MINNESOTA

- - - - - - - - - - - - - - - - - -

In Re:

Bair Hugger Forced Air Warming

Products Liability Litigation

This Document Relates To:

All Actions MDL No. 15-2666 (JNE/FLM)

- - - - - - - - - - - - - - - - - -

DEPOSITION OF JONATHAN BORAK

VOLUME I, PAGES 1 - 251

JULY 20, 2017

(The following is the deposition of JONATHAN BORAK, taken pursuant to Notice of Taking Deposition, via videotape, at the Marriott Hartford Downtown, 200 Columbus Boulevard, Hartford, Connecticut, commencing at approximately 8:09 o'clock a.m., July 20, 2017.)

Q. -- in the left-hand side underneath "Glycemic Control?"
A. Yes.
Q. At the end of it it says, "...Other Guidelines section of the narrative summary for this question (eAppendix 1 one of the Supplement)." Do you see that?
A. Yes.
Q. Okay. Did you look at that supplement to --
A. I believe I did.
Q. Okay. So you're aware that in that supplement the CDC found no benefit to using CHG-alcohol compared to iodophor alcohol; correct?
A. I actually don't recall that.
Q. Okay. Are you aware that the CDC found no benefit to CHG versus povidone-iodine?
A. I don't recall that.
Q. Okay. Would that be something that would be important in connection with your view that the change in skin preparation is a confounder that undercuts the validity of McGovern?
A. I would probably go back and look at it again, and I may do so tonight.
Q. Okay. Are you aware that that appendix found no benefit to using enoxaparin, which is a --

basically a low-molecular-weight heparin similar to trinzaparin, compared to Xarelto, which --
A. I know that it --
MR. GORDON: Object to the form of the question.
A. They -- they reviewed a number of studies, none of which compared trinzaparin.
Q. So you were aware of that.
A. Yes.
Q. And your point is is you can't rely on that because enoxaparin is -- even though it's another type of low-molecular-weight heparin, it's not the same as trinzaparin; correct?
A. Well that was one, and the second is that the papers they reference don't actually define surgical infection.
Q. So with respect --
Well fair point. You'd agree with me that you got to know whether it's a deep joint infection or some other type of infection.
A. I -- I -- I didn't -- I didn't know what they were looking at. I tried. It was cited only --
In each of the four papers they reference there, it is only cited in a table with a footnote, and the footnote doesn't lead -- is a -- is a -- is a

blind path.
Q. Okay. And you set aside the thromboprophylaxis discussion because you didn't see a comparison between -- between trinzaparin and Xarelto directly; correct?
A. I did not see such a comparison.
Q. And you felt like it would be inappropriate to use the reference to enoxaparin even though it's similar to trinzaparin because it's different; is that right?
A. It's different.
Q. And that's one of the reasons you set it aside; correct?
A. Correct.
Q. Now I'd like to direct your attention to page nine of your expert report, Borak Exhibit 1, "The McGovern Study: Background." Are you there?
A. I am.
Q. Okay. And in paragraph 22 you say, "The report -- report by McGovern is the only published study that purports to show an increased risk of SSI associated with the use of the Bair Hugger."
A. I did say that.
Q. Okay. And there --
Since that time there's been the Augustine

paper that's been published; correct?
A. Correct.
Q. And I take it that doesn't change your views.
A. No. I think little of the Augustine paper.
Q. You think little of the Aug --
Why is that?
A. It doesn't seem to follow its protocol. It seems to have cherry-picked data.
Q. What kind of cherry-picking?
A. Hmm. There are data from Ridgeview Medical Center, that were apparently provided under whatever process legally, which shows a compilation of knee and hip surgeries and infectious rates for four years, 2006, 2007, 2008, 2009. Looking at the recent Augustine paper, it appears that he only dealt with the knees, not the hips nor the two combined, that he compared 2006 knees to 2008 and 2009 knees, which was not at all what he said would be the protocol, which was a two-month or three-month washout period, and that he selectickly -- selectively excluded the 2007 data. And so it doesn't look to me as though the Augustine paper is based upon legitimate data, it looks as though -- well "legitimate" -- real but selected in a way to influence the appearance of an

outcome.
Q. How about the other two centers?
A. I don't have any data on them.
Q. Now in paragraph 24 --
Oh, by the way, is there anything else that you want to say about why you think very little of the Augustine paper?
A. Well it's clear that he doesn't provide enough information about the cases, and his statement, which is that nothing else changed, is contradicted by statements from that Ridgeview Medical Center itself, so my sense of it is that the data are not what he presents or that he misrepresents the data, and that he excluded a year's worth of data which would not have enhanced the comparison, that he deviated from the protocol, and that he excluded the hip data.
Q. Excluded the what? I'm sorry.
A. Excluded the hip data --
Q. Oh "hip." Okay. Yeah.
A. -- and did not present the paper properly. He says that he did a replica or something -- I'm paraphrasing -- of the McGovern study, but of course he clearly did not.
Q. If the --
Is that everything? I'm just trying to make

sure.
A. For the moment. It's possible something else will occur to me, but I haven't pulled out my notes.
Q. Okay. If the McGovern study is valid, would you agree with me that there is a substantial increase in the risk of infection through use of the Bair Hugger?
MR. GORDON: Object to the form of the question.
A. Hypothetically, if there were no problems with the McGovern paper, then its conclusions could be relied upon.
Q. Okay. And it would show a substantial increased risk of a deep joint infection --
A. Hypothetically, if it were different --
Q. -- through use of Bair Hugger.
A. Hypothetically, if there were no problems with the McGovern paper and if the results as presented were correct, then it would show a 3.8-fold increased risk with the Bair Hugger that was statistically significant.
Q. Okay. And if --
One of the things that Professor Holford did is say, well, there -- Dr. Reed testified he thought

there was one more infection in each group, then running those numbers is a 2.76 increased risk of infection. Would you consider that substantial?
MR. GORDON: It's actually 2.86.
MS. CONLIN: 2.86. Thank you for that correction.
A. The word "substantial" is awfully subjective. I don't -- I don't think I used it, but maybe I would. I would not use it necessarily for 2.76.
Q. But for 3.8, you would call that a significantly increased odds ratio.
A. I -- I think it was significantly increased. I think that's what the arithmetics showed.
Q. Well you used the term "significantly increased odds ratio" --
A. Yes.
Q. -- for SSI during the Bair Hugger period --
A. Yes.
Q. -- if the McGovern data is accurate; correct?
A. Yes.
Q. Okay. Now in paragraph 24 you say, "The McGovern authors noted that 'unfortunately' during the study period there was a change in the prophylactic

antibiotic regimen and two changes in their thromboprophylaxis regimen." Do you see that?
A. I do.
Q. Where does that quote "unfortunately" come from?
A. I'd have to look and see whether it's in McGovern or in some of the depositions.
Q. Okay. So you weren't suggesting an attribution to the article itself.
A. I don't know. I can look and see. I don't remember.
Q. Okay. And you write in 25 that "The authors concluded that their study did not establish a causal basis for an association between Bair Hugger and risk of SSI...;" correct?
A. Yes, that's correct.
Q. Okay. Now you read the depositions of at least some of the authors; correct?
A. Yes.
Q. Okay. And you understand that they hadn't done a full epidemiological study at the time the McGovern paper was published; correct?
A. I'm not sure what you mean by "a full epidemiological study," but perhaps you can refer to the statement that you're referring to.

EXHIBIT DX22

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

DUKE INFECTION CONTROL OUTREACH NETWORK (DICON)

Infection Prevention News

Volume 10, Number 11, November 2015

HotDogs, Bair Huggers, and Lawsuits, Oh My! A brief review of the controversy surrounding perioperative warming methods.

Maintenance of Perioperative Normothermia: Background and Rationale

A 2-degree Celsius decrease in body temperature in patients undergoing general anesthesia can triple the rate of a postoperative wound infection. The benefits of maintaining normothermia in surgical patients have been extensively studied. These benefits include: 1) reduction of risk of surgical site infection, 2) better coagulation, and 3) faster discharge from the post-anaesthesia care unit. (1, 2)

Maintenance of normothermia is now a standard of care and a key component of the Surgical Care Improvement Project (SCIP). Also, adherence to normothermia protocol is a current requirement for receipt of full reimbursement from CMS. (3)

Most operating rooms, including ours, rely on forced air warming (FAW) devices, such as the Bair Hugger, to ensure normothermia during surgery. FAW warming devices circulate warmed air in a hose connected to a disposable and inflatable blanket. All clinical trials that documented the benefit of maintaining normothermia during surgery have used FAW devices. (1,2)

Resistive Polymer Warming (RPW), FAW's competition:

RPW devices (HotDog) warm patients by passing an electric current through a resistive polymer which in turn is encased in a reusable blanket. In contrast to FAW devices, RPW devices require direct contact with a patient's skin. The warming capacity of RPW devices was compared to that of FAW devices in a 2011 study by Kimberger et al. This study showed that RPW warmed anaesthetized ENT patients at a slower rate. (4)

Current controversies:

Most operating rooms typically utilize "ultraclean air ventilation" during joint replacement procedures. "Ultraclean air ventilation" relies on constant and unidirectional filtered air flow, known as laminar flow, to protect the surgical site from airborne contamination.

A few investigators have speculated that use of FAW devices disrupts laminar flow thus potentially increasing the risk of contamination of the operative site. (5-7) Most studies that reached these conclusions were funded by the manufacturer of a single RPW device. This same company currently

sponsors “informative websites” that emphasize their claims of an increased risk of developing a surgical site infection due to the use of FAW warming devices while simultaneously promoting their alternative RPW product.

A single study done by McGovern et al is the primary source and most commonly quoted evidence for the claim that FAW warming devices are unsafe. (8) These authors evaluated ventilation airflow patterns using a machine that emitted “neutrally buoyant detergent bubbles” during a simulated hip arthroplasty and a lumbar spinal surgical procedure done on mannequins in order determine if laminar airflow was differentially and adversely disrupted by the use of a FAW warming device compared to the use of a RPW warming device. Photographs were used to provide data on “bubble counts” over the operative site during these mock surgical procedures. Bubble counts on operative site over mannequins were higher when FAW devices were used. No actual microbiologic data was collected during this portion of the experiment. (8)

McGovern et al also examined rates of surgical site infection (SSI) after use of either a FAW or RPW warming device in a total of 1,437 patients undergoing knee and hip replacements over a 2.5-year period. They concluded that the risk developing a SSI was higher in patients undergoing arthroplasty procedures when FAW warming devices were used than when RPW warming devices were used (OR 3.8, 95% CI (1.2-12.5), p=0.024). Curiously the risk of developing a SSI was remarkably higher in patients undergoing hip replacement procedures with the use of FAW warming devices than in patients undergoing knee replacements warmed with the same FAW devices (OR 4.1, 95% CI (1.9-8.6), p <0.001). (8)

We and others (3) believe that the preceding widely quoted study by McGovern et al has significant limitations: 1) infection control practices and perioperative antibiotics were not standardized in the two study groups, and 2) the authors did not adjust their outcomes for age or other important patient-related comorbidities. Moreover, the authors failed to discuss what these important details: 1) no mention was made of whether the FAW devices used in this study had proper maintenance including appropriately timed changing of filters in their tubing (see table); 2) they did not provide sufficient supporting data to document that the use of "neutrally buoyant detergent bubbles” are a valid proxy for bacterial contamination, and 3) they did not discuss or explain why patients undergoing hip arthroplasty procedures had such high rates of SSI in their study.

Our take:

The body of evidence describing the link between FAW and increased operative site infections is weak. To the best of our knowledge, no adequately powered, properly controlled, statistically significant, reproducible study has been published that demonstrates an increased risk of SSI due to the use of FAW warming devices. We do not believe that experimental studies using machines that emit bubbles in mock surgical procedures is a proven or standardized method to assess the risk of operative site contamination. Finally, we believe it is important and notable that no studies performed by independent investigators have been published that confirm the findings of the study by McGovern et al. Until such data are published, we believe that it is reasonable and appropriate to continue the use of FAW warming devices in patients. Indeed, our data and that collected by the NHSN suggest that

approximately 99% of patients undergoing joint replacement procedures do not develop a SSI despite the fact that FAW warming devices continue to be widely and appropriately used.

Conclusions:

- We continue to believe that it is reasonable and appropriate to use FAW warming devices to maintain normothermia as these devices are the only devices proven to decrease the risk of developing a post-operative infection.
- FAW warming devices have a >20-year track record of safety in >200 million surgical patients.
- FAW devices should be regularly undergo maintenance as outlined by manufacturer's guidelines, see attached table for recommendations.

References:

1. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. Study of Wound Infection and Temperature Group. N Engl J Med. 1996 May 9;334(19):1209-15.
2. Melling AC, Ali B, Scott EM, Leaper DJ. Effects of preoperative warming on the incidence of wound infection after clean surgery: a randomised controlled trial. Lancet. 2001 Sep 15;358(9285):876-80.
3. Sikka R, Prielipp R. Forced Air Warming Devices in Orthopaedics: A Focused Review of the Literature. J Bone Joint Surg Am. 2014; 96:e200(1-7).
4. Kimberger O, Held C, Stadelmann K, Mayer N, Hunkeler C, Sessler DI, Kurz A. Resistive polymer versus forced-air warming: comparable heat transfer and core rewarming rates in volunteers. Anesth Analg. 2008 Nov;107(5):1621-6.
5. Albrecht M, Gauthier RL, Belani K, Litchy M, Leaper D. Forced-air warming blowers: An evaluation of filtration adequacy and airborne contamination emissions in the operating room. Am J Infect Control. 2011 May;39(4):321-8.
6. Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? Orthop Rev (Pavia). 2009 Oct 10;1(2):e28.
7. Legg AJ, Hamer AJ. Forced-air patient warming blankets disrupt unidirectional airflow. Bone Joint J. 2013 Mar;95-B(3):407-10.
8. McGovern PD, Albrecht M, Belani KG, Nachtsheim C, Partington PF, Carluke I, Reed MR. Forced-air warming and ultra-clean ventilation do not mix: an investigation of theatre ventilation, patient warming and joint replacement infection in orthopaedics. J Bone Joint Surg Br. 2011 Nov;93(11):1537-44.

Warming Unit Information and Table

"The repair, calibration, and servicing of the warming unit requires the skill of a qualified medical equipment service technician who is familiar with good practice for medical device repair" —3M Bair Hugger Manual (http://multimedia.3m.com/mws/media/798399O/service-manual-english.pdf)

Refer to your model manual for exact specifications. The table below is a general guide, and should not replace model specific guidelines.

TABLE I

Proper Maintenance and Use of Forced Air Warmers

Recommendations
1. The filter should be changed every 6 months or 500 hours. A counter is available on some devices (e.g., Bair Hugger 700 series) to indicate the total hours of use.
2. Calibration testing should occur every six months by biomedical engineering staff at the user's institution. The manufacturer should check or replace devices that fail calibration testing.
3. Do not warm patients with the warming unit's hose alone, as severe thermal injury may occur. Always connect the hose to a new, manufacturer-approved warming gown for each patient.
4. Do not continue warming if the red over-temperature indicator light illuminates or an audible alarm sounds, as thermal injury may result. Turn the warming unit off immediately and check the patient's skin.
5. Do not use a forced air warming device over transdermal medications; increased drug delivery and patient death or injury may result.
6. Do not allow the patient to lie on the warming unit hose or allow the hose to contact the patient's skin during patient warming.
7. Equipment is not suitable for use in the presence of a flammable anesthetic mixture (e.g., containing air, oxygen, or nitrous oxide).
8. Do not place the non-perforated side of the blanket on the patient. Thermal injury may result. Always place the perforated side (the side with small holes) toward the patient.

Recommendations
9. The warming device should be disconnected from the power source before cleaning. Between patients, the outside of the hose should be cleaned with a damp, soft cloth and a mild detergent or antimicrobial spray and then dried with a separate cloth.
10. If a fault occurs in the unit, unplug the temperature management unit and wait for five minutes. Reconnect the temperature management unit to a grounded power source. The unit will perform the normal power-on-reset sequence and then enter the standby mode. If the unit does not return to normal operation, contact a service technician.
11. Temperature and calibration testing should be performed every 6 months or 500 hours of use.

Taken from Sikka, RS *J Bone Joint Surg Am*, 2014 Dec 17; 96 (24): e200 .
http://dx.doi.org/10.2106/JBJS.N.00054

EXHIBIT DX23

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

The Journal of Arthroplasty 32 (2017) 2307–2314

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Review

Normothermia in Arthroplasty

Mark W. Allen, DO, David J. Jacofsky, MD *

Department of Orthopedics, The CORE Institute, Phoenix, Arizona

ARTICLE INFO

Article history:
Received 14 September 2016
Received in revised form
2 January 2017
Accepted 6 January 2017
Available online 17 January 2017

Keywords:
normothermia
arthroplasty
total hip arthroplasty
total knee arthroplasty
warming strategies

ABSTRACT

Background: Since the initial design of surgical theatres, the thermal environment of the operating suite itself has been an area of concern and robust discussion. In the 1950s, correspondence in the British Medical Journal discussed the most suitable design for a surgeon's cap to prevent sweat from dripping onto the surgical field. These deliberations stimulated questions about the effects of sweat-provoking environments on the efficiency of the surgical team, not to mention the effects on the patient. Although these benefits translate to implant-based orthopedic surgery, they remain poorly understood and, at times, ignored.
Methods: A review and synthesis of the body of literature on the topic of maintenance of normothermia was performed.
Results: Maintenance of normothermia in orthopedic surgery has been proven to have broad implications from bench top to bedside. Normothermia has been shown to impact everything from nitrogen loss and catabolism after hip fracture surgery to infection rates after elective arthroplasty.
Conclusion: Given both the physiologic impact this has on patients, as well as a change in the medicolegal environment around this topic, a general understanding of these concepts should be invaluable to all surgeons.

Normothermia

The body normally maintains its temperature between 36°C and 38°C by balancing heat production and heat loss to maintain a state of normothermia [1-3]. These functions are controlled by the thermoregulatory systems in the central nervous system [2]. The body loses heat through radiation, conduction, evaporation, and convection. In surgery, this may occur via tissue loss (radiation), contact with cool operating surfaces (conduction), respiration (evaporation), and exposure to the environment itself (convection) [3]. To complicate matters, the central nervous system is disrupted under anesthesia and the body's thermoregulatory systems are unable to function normally; thus, both hypothermia, a core temperature <36°C, and hyperthermia, a core temperature >38°C, may occur during surgical procedures [2]. Under general anesthesia, the average adult loses 0.5°C-1.5°C, with most heat loss occurring during the first hour of the procedure [3].

Anesthetic-induced vasodilation allows core heat to flow peripherally, warming the arms and legs at the expense of core temperature maintenance [4]. Temperature and humidity ranges in the operating room often are set by local codes or by industry accepted guidelines [5]. Thus, the patient's core temperature should be continuously monitored throughout procedures. Reliable sites of core temperature monitoring include the tympanic membrane, nasopharynx, esophagus, bladder, rectum, and pulmonary artery [6]. Core temperature is most accurate when measured from the pulmonary artery, which is the gold standard for monitoring [2]. However, due to invasiveness, nasopharyngeal, esophageal, and urinary bladder temperatures are used instead and correlate well with pulmonary artery temperature, except during rapid changes [7]. Maintaining normothermia preoperatively, intraoperatively, and postoperatively has since become the standard of care for surgical patients. Yet despite its proven and critical importance, many specialists often treat it with a laissez-faire attitude.

Physiologic Impact of Failing to Maintain Normothermia

There are many drivers of hypothermia in the surgical patient. These include the use of large volumes of cool fluid for irrigation, major blood or fluid loss, exposure of a large body cavity to the external environment, patient's age, patient's physical status or preexisting conditions, a cold surgical suite, type of anesthesia used, and length and type of surgical procedure [3]. Complications associated with hypothermia include altered metabolism, wound infections, shivering, cardiovascular effects, and coagulopathy with

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2017.01.005.

* Reprint requests: David J. Jacofsky, MD, Department of Orthopedics, The CORE Institute, 18444 N 25th Ave., Phoenix, AZ 85023.

http://dx.doi.org/10.1016/j.arth.2017.01.005
0883-5403/

an increase in surgical bleeding [3]. Even mild hypothermia in a surgical patient can result in devastating physiologic consequences.

The metabolic system is disrupted during hypothermia. An healthy individual maintains a physiologically normal pH of 7.35-7.45 through a complex balance of hydrogen ions and buffers predominantly controlled by the pulmonary and renal systems [8]. Acidosis is defined as an arterial pH <7.35 and can result from a variety of disease states. In surgical patients, a major contributor of becoming acidotic is poor perfusion to the tissues [9]. Oxygen delivery to the tissues may be impaired during surgery due to anemia from acute blood loss, peripheral vasoconstriction in response to hypothermia and blood loss, and overall decreased cardiac output resulting in tissue oxygen demand far exceeding oxygen delivery. Furthermore, decreased temperatures also shift the oxygen dissociation curve to the left, decreasing oxygen delivery to the target tissues. Thus, to make functional energy, the body's cells are forced to utilize anaerobic metabolism, resulting in the production of lactic acid as a byproduct [10]. Acute metabolic acidosis decreases cardiac contractility and cardiac output, arterial vasodilation develops, and patients become hypotensive [11-14].

Wound infections, unfortunately, are common and serious complications of surgery and are more likely in hypothermic patients. Hypothermia increases patients' susceptibility to perioperative wound infections by causing vasoconstriction and impaired immunity [15]. The presence of sufficient intraoperative hypothermia triggers thermoregulatory vasoconstriction, decreasing the partial pressure of oxygen in tissues, thus lowering resistance to infection [16-19]. In turn, this also causes a decrease in microbial killing, as this is dependent on production of oxygen and nitrous free radicals which cannot be formed in the range of the depleted partial pressures of oxygen in the wounds of a hypothermic patient [20,21]. Mild core hypothermia can also directly impair immune functions, such as the chemotaxis and phagocytosis of granulocytes, the motility of macrophages, the production of antibodies, and impair oxidative killing by neutrophils [22,23]. Vasoconstriction-induced tissue hypoxia decreases the strength of the healing wound independently of its ability to reduce resistance to infection. The formation of scar requires the hydroxylation of abundant proline and lysine residues to form the cross-links between strands of collagen that give healing wounds their tensile strength and are dependent on oxygen tension, which is decreased in hypothermic patients [24-27].

Due to a multitude of possible complications, avoidance of shivering is necessary in surgical patients. Hypothermia causes shivering which can increase the metabolic rate up to 5-fold [28] causing a further increase in oxygen demand and a depletion of glycogen in the muscles [29] and high-energy phosphate stores [30]. Hypothermia is also associated with up to a 250% increase in minute ventilation [31], which may be detrimental in patients with underlying conditions, especially those involving the lung.

With further hypothermia, decreases in heart rate and slowing of metabolism reduce cardiac afterload and oxygen demand [32]. Hypothermia increases systemic vascular resistance along with central venous pressure, maintaining mean arterial pressure [32]. ECG changes in a hypothermic patient include an increased PR interval, widened QRS complex, and the appearance of the “J wave” (a notch on the downstroke of the QRS complex) [32]. The exact mechanism by which mild hypothermia triggers myocardial events remains unclear. Cold-induced hypertension in the elderly is associated with a 3-fold increase in plasma norepinephrine concentrations [33], which may augment cardiac irritability and facilitate development of ventricular arrhythmias. However, adverse cardiac events have been demonstrated only in patients with probable coexisting coronary atherosclerotic disease. The largest study to employ therapeutic hypothermia for surgical patients demonstrated no increase in the use of vasopressors, arrhythmias (other than sinus bradycardia), myocardial ischemia, or myocardial infarction in the group that underwent hypothermia [34,35]. The authors hypothesized that this was due to the low incidence of coexisting coronary atherosclerotic disease in their surgical study group.

Hypothermia disrupts the coagulation system. Importantly, the standard coagulation tests (prothrombin time and activated partial thromboplastin time) are not helpful to reflect these changes as they are performed at room temperature regardless of what the actual patient's temperature may be, and therefore may inappropriately lead a physician to believe that bleeding should be well controlled [32]. The coagulation system is a temperature and pH-dependent series of complex enzymatic reactions that result in the formation of blood clots to stop both internal and external bleeding [36]. Coagulopathy is the term used to describe a broad group of disease states in which there is an impaired ability of this coagulation system to form blood clots [36]. As a patient's core temperature cools, there is impairment in the body's ability to stop bleeding due to impaired platelet function, inhibition of clotting factors, and inappropriate activation of clot breakdown [37]. During hypothermia, the spleen and liver may sequester platelets further impairing the coagulation cascade and thus further increasing blood loss [38]. Hypothermia appears to impair clot formation rather than facilitate clot degeneration [39]. Although platelet numbers generally remain normal during mild hypothermia, platelet function is impaired [40-42]. A meta-analysis of literature, along with other supporting publications, demonstrated that a patient with a mean temperature of 35.6°C was likely to lose 16% more blood and was 22% more likely to receive a blood transfusion than a patient with normal temperature [9,38]. This increased rate of transfusion due to hypothermia also increases the risk of perioperative infection due to the allogeneic transfusion itself.

Warming Strategies and Devices

Perioperative hypothermia remains common, although there are several proven, safe, and inexpensive methods of warming available. Effective warming systems must regulate for cutaneous heat loss, because roughly 90% of metabolic heat is lost through the skin surface [43]. Available systems can be categorized as passive insulation or active cutaneous heating. These devices can be utilized preoperatively, intraoperatively, and postoperatively to maintain normothermia in arthroplasty surgical patients.

Passive Warming

Passive systems involve layers of insulation, like blankets or other types of surgical draping. A single layer of virtually any passive insulator reduces cutaneous heat loss by roughly 30% [43]. A plastic bag or a single layer of surgical draping retains heat nearly as well as cotton blankets or metalized plastic covers (“space blankets”) [17]. Interestingly, the cover itself provides relatively little insulation—the heat is retained in the layer of still air between the cover and the skin. Increasing the number of insulating layers (adding blankets) decreases heat loss by an additional 20% [44]. Using warmed blankets does not help as final cutaneous heat loss is virtually identical whether the blankets are initially warm or not [44]. Warmed blankets are an easy addition to any orthopedic surgical patient regardless of the patient's positioning.

Active Warming

In theory, passive insulation can reduce cutaneous heat loss completely and increase mean body temperature roughly 1°C/h, depending on the metabolic rate and size of the patient [43]. In practice, however, even the best passive insulation rarely reduces heat loss even by 50% [17,44], especially when variables of surgical

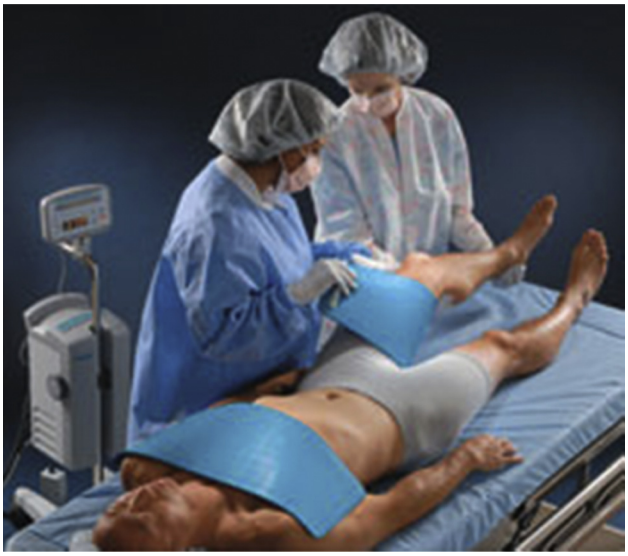


Fig. 1. KC M1000 Warming Pads (Patient Warming System M1000; Kimberly Clark).

Fig. 2. Bair Hugger upper body warming blanket (3M Company).

intervention are introduced. Active cutaneous warming is thus required to maintain normothermia in patients during surgery [45]. There are many active warming systems available for surgical patients. Technologies include circulating water, forced air, resistive heating, radiant warmers, negative-pressure warming, hot water containers, fluid warming, airway heating and humidification, and other internal warming methods.

Active Warming: Circulating-Water Devices

The classic active intraoperative warming system that has been used for decades is the circulating-water mattress. These devices include energy transfer pads (Patient Warming System M1000; Kimberly Clark, Roswell, GA) (Fig. 1), Arctic Sun Pads (Bard Medical Division, Covington, GA), and circulating-water garments (Allon MTRE 3365 for cardiac surgery; Akiva, Israel). Circulating-water devices have been hypothesized to be more effective mediums to transfer heat than forced air devices due to the greater specific heat capacity [46] and thermal conductivity [47] they provide. Unfortunately, in practice, efficacy of the mattresses is limited due to positioning of the mattress underneath the patient, as the back contains only a small fraction of total body surface area [43]. About 90% of metabolic heat is still lost from the anterior surface of the body and any effective heat transferring through the back cannot compensate for the larger anterior losses [48].

An additional problem with circulating-water warming is that the technique is associated with pressure-heat necrosis [49,50]. Thus, water mattresses must operate at lower [50] temperatures to prevent pressure heat necrosis. Circulating-water warming is effective when positioned over patients instead of its normal posterior positioning, making it safer as the risk of pressure-heat necrosis is then reduced [51]. However, positioning these mattresses over the patients is not conducive to most orthopedic operative procedures.

Water garment heating provides a much larger surface area for heating with both anterior and posterior heating access. One study estimated that water garments were able to warm up to 80% of a patient's total body surface area compared with only 20%-40% using upper body forced-air warming during open abdominal surgery [52]. Circulating-water garments have shown greater ability to achieve significantly higher core temperature profiles compared with forced-air warming [46,52-55]. However, there have been numerous documented cases involving burns with water-warming devices [56,57]. Incorrect assembly of a negative-pressure water-warming device [58] led to 2 burns in the same trial. Other reported burns have been associated with full body water garments [56] and circulating-water mattresses [57]. Surface damage to the patient's skin is difficult to manage as this posterior surface is vulnerable to pressure-heat necrosis from reduced perfusion and also cannot be easily observed during the operation. Due to these risks and the issues of practicality, these devices have fallen out of favor in many hospitals.

Circulating-water pads can be positioned on arthroplasty patients in both lateral and supine positions during surgery. Many of these pads have an adhesive side allowing for direct contact to the skin, maximizing heat transfer. These pads can contact the upper thorax and non-operative leg during supine total knee arthroplasty (TKA) and total hip arthroplasty (THA). In the lateral position, these pads can be placed on the anterior chest wall, back, and lateral thorax, as well as the upper shoulder and arm. Attention should be paid, however, to avoid placing patients directly on top of the heating pads to avoid pressure-heat necrosis.

Active Warming: Forced Air

Forced-air warming systems combine an electrically powered heater blower unit with a patient cover made of fabric, plastic, or paper that is usually disposable after single patient use. The blowers are available in various sizes and configurations. Forced-air warming works by both reducing radiant heat loss through a warm cover and providing convective heat through warm air moving rapidly over the skin.

There are numerous forced-air convection warmer systems available to prevent perioperative hypothermia, although few studies have directly compared them. These devices include the Bair Hugger system (3M Company, Maplewood, MN) (Fig. 2), WarmTouch (Mallinckrodt Medical, Inc, St. Louis, MO), ThermaCare (Gaymar Industries, Orchard Park, NY), and WarmAir (Cincinnati Sub-Zero Products, Cincinnati, OH). The Bair Hugger system has better total heat transfer compared to the other systems when used to warm nonanesthetized healthy volunteers with full body blankets [59]. The WarmTouch system demonstrated the highest heat transfer when upper body blankets were used [60]. There were no significant differences in total heat transfer found between forced-air warming devices when only lower body blankets were used [61]. Forced-air systems surpass passive insulation and provide considerably more heat than circulating water [51,62,63].

Preoperative warming with forced air has been demonstrated to increase the heat content of peripheral tissues by more than what is normally lost through temperature redistribution during the hour following induction of anesthesia [64]. Prewarming patients with forced air compared to warmed cotton blankets have shown a significantly higher temperature upon admission to the Post-anesthesia care unit (PACU) after surgery [65]. Use of the Bair Paws (3M Company) patient warming system for 60 min of prewarming at 38°C demonstrated a significantly smaller decrease in mean core temperature and maintained patients above the hypothermic threshold significantly better perioperatively [66].

It has been hypothesized that perhaps forced-air warming devices may increase surgical site infection rates through convection currents generated in the operative theater air. McGovern et al [67] questioned the safety of using forced-air warming during orthopedic cases. Forced-air warming creates a significant temperature gradient in the operating room, which can disrupt laminar flow patterns [68]. Ultraclean laminar airflow operating rooms are designed to move air vertically with a consistent downward velocity of air theoretically causing decreased airborne particulate contamination of the surgical site. These systems are dependent on consistency of temperature and volume of airflow. Disruption of this airflow pattern can potentially increase surgical site infections as sites become contaminated by floor level air becoming mobilized by convection currents [67]. McGovern et al used a bubble generator to visualize air currents and compared forced-air warming to conductive fabric warming in simulated THA and spine surgery performed in laminar airflow equipped operating rooms. It was shown that the bubble counts were higher at the surgical sites, presumably because forced-air warming mobilized under drape air into the surgical site. The authors concluded that forced-air warming was incompatible with ultraclean operating rooms. Another study demonstrated that sampled air in the operative field of laminar flow theatres showed small increases in colony-forming units when forced-air warmers were turned on, although the authors deemed these unlikely to have significance [69]. It has also been hypothesized that the air warmer host itself can emit microbial pathogens onto the operating field [70-72]. Currently, a number of lawsuits have been filed regarding the use of forced-air warming during arthroplasty surgery. These lawsuits focus on the possible relationship between a forced-air device being used during an arthroplasty procedure and the subsequent development of a prosthetic joint infection.

The correct use of microbial filters and the device's recommended perforated blankets has been shown to prevent the spread of microbial pathogens onto the operating field [70]. Proper maintenance of these devices is imperative to minimize colonization. Many studies have shown forced-air warming to be safe to use in laminar airflow equipped operating rooms. Sessler et al [73] tested the air quality in laminar flow equipped operating rooms using a forced-air warming device under 3 different settings. They ultimately concluded that there was no deterioration in the air quality with the use of forced-air warming with ambient or warm air and no statistically significant difference in particle concentration between having the machine turned on or turned off, deeming forced-air warming devices are safe to use. At least 6 independent, peer-reviewed studies have demonstrated that forced-air warming does not increase bacteria dispersion near the patient [69,70,74-77]. Independent randomized control studies have shown that perioperative temperature management with forced-air warming actually decreases surgical site infection risk in patients [15]. Based on the available evidence present at this point, there is no scientific proof that the use of forced-air warming leads to an increase in surgical site infections regardless of the type of surgical procedure and the type of operating room [78].

Caution when using the device should include proper positioning of the blanket, tubing, and heater unit, along with scheduled maintenance and cleaning of the heater unit. People are the largest single contributor to infection by airborne contaminants [79] in operating rooms as one billion skin cells are shed daily per person [80], with up to 10% carrying bacteria [81]. Thus, limiting operating room traffic is critical to decreasing prosthetic joint infections regardless of warming technology.

If not careful, however, forced-air warming devices can cause thermal injuries in both adults [82-84] and children [85-87]. Care must be taken to prevent thermal injury. Proper use of forced-air warming devices includes preventing direct contact of warm air with the patient's skin, proper placement of the warming gown on the patient, preventing the blanket from being compressed causing hotspots, and making sure that the heated air tubing does not contact the patient. In the majority of cases, the underlying cause involved incorrect assembly of the warmer hose to the blanket or accidental disconnections which allowed hot air to blow directly on the patient's skin for a prolonged period of time.

Forced-air warming blankets can be easily applied to patients in the supine position covering a large surface area during supine TKA and THA. They can also be applied to the exposed lateral thorax, upper shoulder, and arm during THA in the lateral decubitus position. These devices are not as easily applied to the non-operative leg during TKA due to the blanket being compressed by the overlying drapes.

Active Warming: Resistive Heating Blankets

Resistive heating is supplied by use of an electric-type blanket. According to clinical studies, the efficacy of resistive heating is similar to that of forced air [88]. Resistive heating may be especially helpful for field treatment of accidental hypothermia as they are highly efficient devices and can run on battery power alone [89].

Resistive heating blankets such as the Hot Dog Warming Blanket (Augustine Biomedical, Eden Prairie, MN), Inditherm mattress (Inditherm plc, Rotherham, UK), Pintler Warming Pad (Pintler Medical LLC, Seattle, WA), and Klimamed Thermal Mat System (KLIMAmed Technology, Herrenberg, Germany) have been shown to achieve significantly higher patient core temperatures than passive insulation [90] or no warming at all [88,91]. The majority of clinical trials comparing resistive heating to forced-air warming have shown equivalence [92-97] between devices with 3 favoring forced-air warming superiority [98-100].

Resistive blankets are easy to use and can be set up and turned on prior to induction of anesthesia. Prewarming of patients can be performed with the use of resistive heating blankets. They do not interfere with surgical draping or skin preparation and can be started immediately upon transfer of the patient to the operating table. Initiating the resistive blankets this early allows for preinduction core temperature warming which has been shown to attenuate redistributive heat loss. The maximal effect takes 2 h to achieve [64], although periods even as short as 10 min have shown significant effects [101]. Resistive blankets do not produce air convection currents that may interfere with laminar flow and avoid the possibility of circulating contaminants throughout the operating room.

Significant burns can be caused by the mattress or blanket itself if temperatures become inappropriately elevated. A fault within a resistive heating mattress causing a localized hotspot in a Klimamed mat caused full thickness burns requiring split thickness skin grafting and scar therapy in 2 pediatric patients [102]. In the instructions for use for the Hot Dog Warming Blanket, it states “DO NOT place warming blanket under patient.” This is a testament to the risk associated with compression heat burns and providers must understand the risks associated with placing these devices under patients.

Various sizes and shapes, along with flexibility of the devices, allow for resistive heating blankets to provide versatility in use during arthroplasty procedures. These devices can be used in both the supine and lateral position for TKA and THA. They can be used under drapes on the nonoperative leg during TKA and can cover both arms in the supine position.

Active Warming: Radiant Warmers

Radiant warmers provide heat using special incandescent bulbs or heated surfaces to generate infrared radiation [43]. Advantageously, in radiant heating, the heat energy does not depend on the intervening air so there does not have to be contact between the warmer and the patient. Radiant heating is ideal in places where the patients should remain visible, like in neonatal intensive care units, or while patients are undergoing different procedures where they need to be exposed, like in pediatric surgery cases or trauma patients. A major limitation of radiant heating is that convective losses are ongoing as so much of the body is exposed. The distance between the warmer and the patient also limits radiant warmers' effectiveness and closer distances may get impractical in the patients whom theoretically most benefit from the technology. As the distance increases, or when the warming surface and the skin surface are not parallel to each other, the energy transfer decreases rapidly. In most cases, the limitations of radiant heating combine to make this method relatively ineffective in surgery compared with other cutaneous warming systems. This technology is not currently used in arthroplasty surgery.

Active Warming: Negative-Pressure Warming

Negative-pressure warming uses the theory that negative pressure will be able to overcome the effects of thermoregulatory vasoconstriction, allowing better heat transfer from a patient's periphery to their core [103]. The “Thermo-Stat” device uses a vacuum system that is applied to the hand and forearm to facilitate peripheral-to-core heat transfer [104]. The inventor published 2 studies showing remarkable rates of core warming [104,105], but further independent studies failed to confirm any significant benefit from negative-pressure warming [106,107]. General anesthesia causes peripheral vasodilation and the maximum effect of negative-pressure heating cannot overcome this barrier to adequately warm a patient's core, but rather is a synergistic strategy. The hand and upper extremity is readily accessible during positioning for TKA and THA; however, these devices are not currently used during arthroplasty procedures.

Active Warming: Hot Water Bottles

Another possible warming method for surgical patients is to position warm containers in areas of high blood flow, like the axilla. Plastic containers of normal saline are frequently kept in warmers near operating rooms with ovens often exceeding 45°C. This warming practice, however, is both ineffective and dangerous. Despite placing the warm bottles in regions of high blood flow, lack of efficacy results because the surface area involved is small. Unfortunately, the heat accumulates locally, causing burns to the tissue that is directly in contact with the warm container. An analysis of the American Society of Anesthesiologists closed claims database indicated that hot water bottles were by far the leading cause of perioperative thermal injury [57]. Hot water bottles should therefore never be used to warm surgical patients.

Active Warming: Warm Fluids

Heat loss caused by cold intravenous fluids becomes significant when large volumes of crystalloid solution or blood are administered as one unit of refrigerated blood or 1 L of crystalloid solution administered at room temperature decreases the mean body temperature to about 0.25°C in adults [108]. Fluid warmers minimize these losses and should be used when large amounts of intravenous fluid or blood are administered. However, fluid warming does not warm patients to any important extent because it is unsafe to heat fluids much above normal body temperature. Fluid warming is therefore not a substitute for cutaneous warming, but rather a synergistic strategy. Fluid warming is utilized at the discretion of the anesthesiologist during arthroplasty cases.

Active Warming: Active Airway Heating

Another intraoperative heating method involves active airway heating and humidification. About 10% of metabolic heat production is lost via the respiratory tract, but theoretically, respiratory heat transfer maintains core temperature slightly better than a comparable amount of heat applied to the skin surface because the heat is transferred directly into the core compartment. However, many studies of active heating and humidification report that warming inspiratory gases contributes little to preservation of core temperature in adults undergoing large operations as the total amount of heat transferred is so small [48]. Some studies that showed an apparent clinical benefit [109] may have resulted from artificial warming of a temperature probe positioned in the nasopharynx or upper esophagus [110]. Hygroscopic condenser humidifiers and heat and moisture exchanging filters (“artificial noses”) retain substantial amounts of moisture and heat within the respiratory system. They are roughly half as effective as active systems in terms of maintaining core temperature [111]; however, they cost only a fraction as much. In polytrauma patients, where large areas of the body are exposed during resuscitation or multisite simultaneous surgery, this may be a strategy that will contribute to slowing the rate of loss of core body heat.

Maintaining Normothermia in Orthopedic Patients

As shown in general surgery, maintaining normothermia in orthopedic patients during surgery is also important for minimizing intraoperative problems and preventing possible postoperative complications. In patients undergoing THA, aggressive warming decreases intraoperative blood loss and allogenic blood transfusions [112]. Specifically, the use of forced-air warming to maintain normothermia has been shown to decrease blood loss, transfusion needs, and postanesthesia recovery time in patients undergoing THA [38,112,113]. A prospective study by Bennett et al [114] compared 45 patients undergoing elective hip arthroplasty under general anesthesia assigned to 3 different groups—no active intraoperative warming (control group), a passive warming modality (the Thermolite metalized plastic sheet), or active forced-air warming with Bair Hugger therapy. The authors concluded that Bair Hugger therapy was the most efficient in regulating patient temperature during THA. Maintenance of normothermia is of utmost importance in elderly patients who sustain hip fractures in order to decrease morbidity and mortality. A recent study found that intraoperative hypothermia occurs in 13.2% of patients undergoing operative intervention for hip fractures, which likely contributed to an increase in the rate of deep surgical site infection [115]. Leijtens et al [116] also showed that patients who developed hypothermia during THA were 3.7 times more likely than normothermic patients to develop a periprosthetic infection.

In patients undergoing TKA, use of warming gowns compared to standard blankets was shown to significantly increase postoperative temperatures and decrease the use of postoperative opioid medication [117]. A comparative study of maintenance of body temperature during TKA has shown to be equivalent with the use of an electric heating pad when compared to forced-air heating [97].

Cost and Possible Return on Investment

Hypothermia averaging only 1.5°C less than normal has resulted in cumulative adverse outcomes costing between $2500 and $7000 per surgical patient to hospitalization costs across a variety of surgical procedures [118]. Hypothermia itself, shivering, and complications also reduce patient satisfaction.

The direct financial costs vary depending on the warming technology chosen. At our facility, the disposable forced-air warming blankets (Bair Hugger) that are used cost approximately $6.15 per case. As a higher volume facility, the units are provided for free. Pricing for disposable Arctic Sun by Bard is quoted as a $55,000 capital purchase for a controller and a range for gel pads from $339 to $1048 per case. KC Halyard disposable thermal blankets run $165 per case. The Pintler Warming Pad charges $2500 per table pad and are reusable. The Hot Dog Warming Blanket, also reusable, costs $1450 per blanket and $2925 for the controller. Although reusable, these blankets have a finite life span with expiration dates after which they must be replaced.

Summary

Maintenance of perioperative normothermia is of paramount importance in reducing perioperative complications. There are many different types of warming devices that utilize various heating technologies. The benefits and costs of proper use of these devices significantly outweigh the risks associated with perioperative hypothermia. Proper use and maintenance of these devices is critical to improving overall patient outcomes. Forced-air warming devices may be the most cost effective, especially in low to mid-volume centers. Despite recent controversy about forced-air warming devices, the literature does not support an increased risk for infection with such technologies. Additional prospective, randomized, head-to-head studies need to be performed to determine if any one particular product is clinically superior within different classes of these devices.

References

1. Ellis FP. The control of operating-suite temperatures. Br J Ind Med 1963;20:284.
2. Sappenfield JW, Hong CM, Galvagno SM. Perioperative temperature measurement and management: moving beyond the Surgical Care Improvement Project. J Anesthesiol Clin Sci 2013;2:8.
3. *AST guideline statement for the maintenance of normothermia in the perioperative patient*. 1, ast.org; 2014 [accessed 01.07.16].
4. Matsukawa T, Sessler DI, Sessler AM, et al. Heat flow and distribution during induction of general anesthesia. Anesthesiology 1995;82:662.
5. Murphy J. *Temperature & humidity control in surgery rooms*. Atlanta, GA: Ashrae; 2006.
6. Forstot RM. The etiology and management of inadvertent perioperative hypothermia. J Clin Anesth 1995;7:657.
7. Akata T, Setoguchi H, Shirozu K, et al. Reliability of temperatures measured at standard monitoring sites as an index of brain temperature during deep hypothermic cardiopulmonary bypass conducted for thoracic aortic reconstruction. J Thorac Cardiovasc Surg 2007;133:1559.
8. Trauma's lethal triad of hypothermia, acidosis & coagulopathy create a deadly cycle for trauma patients. Gerecht R, MD. J Amer Med Serv. April 2014. PennWell Corporation. Tulsa, OK.
9. Rajagopalan S, Mascha E, Na J, et al. The effects of mild perioperative hypothermia on blood loss and transfusion requirement. Anesthesiology 2008;108:71.
10. Weingart S, Meyers CM. Thoughts on the resuscitation of the critically ill trauma patient. EMCrit Blog. 2008. http://emcrit.org/wp-content/uploads/resus-of-crit-ill-trauma-patients.pdf; [accessed 26.01.17].
11. Mitchell JH, Wildenthal K, Johnson RL. The effects of acid-base disturbances on cardiovascular and pulmonary function. Kidney Int 1972;1:375.
12. Teplinsky K, O'Toole M, Olman M, et al. Effect of lactic acidosis on canine hemodynamics and left ventricular function. Am J Physiol 1990;258:H1193.
13. Wildenthal K, Mierzwiak DS, Myers RW, et al. Effects of acute lactic acidosis on left ventricular performance. Am J Physiol 1968;214:1352.
14. Kellum JA, Song M, Venkataraman R. Effects of hyperchloremic acidosis on arterial pressure and circulating inflammatory molecules in experimental sepsis. Chest 2004;125:243.
15. Kurz A, Sessler DI, Lenhardt R. Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization. N Engl J Med 1996;334:1209.
16. Ozaki M, Sessler DI, Suzuki H, et al. Nitrous oxide decreases the threshold for vasoconstriction less than sevoflurane or isoflurane. Anesth Analg 1995;80:1212.
17. Sessler DI, McGuire J, Sessler AM. Perioperative thermal insulation. Anesthesiology 1991;74:875.
18. Chang N, Mathes SJ. Comparison of the effect of bacterial inoculation in musculocutaneous and random-pattern flaps. Plast Reconstr Surg 1982;70:1.
19. Jönsson K, Hunt TK, Mathes SJ. Oxygen as an isolated variable influences resistance to infection. Ann Surg 1988;208:783.
20. Hohn DC, MacKay RD, Halliday B, et al. Effect of O2 tension on microbicidal function of leukocytes in wounds and in vitro. Surg Forum 1976;27:18.
21. Mader JT, Brown GL, Guckian JC, et al. A mechanism for the amelioration by hyperbaric oxygen of experimental staphylococcal osteomyelitis in rabbits. J Infect Dis 1980;142:915.
22. Van Oss CJ, Absolom DR, Moore LL, et al. Effect of temperature on the chemotaxis, phagocytic engulfment, digestion and O2 consumption of human polymorphonuclear leukocytes. J Reticuloendothel Soc 1980;27:561.
23. Leijh PC, Van den Barselaar MT, Van Zwet TL, et al. Kinetics of phagocytosis of *Staphylococcus aureus* and *Escherichia coli* by human granulocytes. Immunology 1979;37:453.
24. Prockop DJ, Kivirikko KI, Tuderman L, et al. The biosynthesis of collagen and its disorders. N Engl J Med 1979;301:13.
25. De Jong L, Kemp A. Stoichiometry and kinetics of the prolyl 4-hydroxylase partial reaction. Biochim Biophys Acta 1984;787:105.
26. Hunt TK. The effect of varying ambient oxygen tensions on wound metabolism and collagen synthesis. Surg Gynecol Obstet 1972;135:561.
27. Jönsson K, Jensen JA, Goodson WH, et al. Tissue oxygenation, anemia, and perfusion in relation to wound healing in surgical patients. Ann Surg 1991;214:605.
28. Eyolfson DA, Tikuisis P, Xu X, et al. Measurement and prediction of peak shivering intensity in humans. Eur J Appl Physiol 2001;84:100.
29. Haman F. Shivering in the cold: from mechanisms of fuel selection to survival. J Appl Physiol 2006;100:1702.
30. Marion D, Bullock MR. Current and future role of therapeutic hypothermia. J Neurotrauma 2009;26:455.
31. Horvath SM, Spurb GB, Hutt BK, et al. Metabolic cost of shivering. J Appl Physiol 1956;8:595.
32. Luscombe M, Andrzejowski JC. Clinical applications of induced hypothermia. Contin Educ Anaesth Crit Care Pain 2006;6:23.
33. Frank SM, El-Gamal N, Raja SN, et al. α-Adrenoceptor mechanisms of thermoregulation during cold challenge in humans. Clin Sci 1996;91:627.
34. Todd MM, Hindman BJ, Clarke WR, et al. Intraoperative Hypothermia for Aneurysm Surgery Trial (IHAST) Investigators. Mild intraoperative hypothermia during surgery for intracranial aneurysm. N Engl J Med 2005;352:135.
35. Nguyen HP, Zaroff JG, Bayman EO, et al. Perioperative hypothermia (33°C) does not increase the occurrence of cardiovascular events in patients undergoing cerebral aneurysm surgery findings from the intraoperative hypothermia for aneurysm surgery trial. Anesthesiology 2010;113:327.
36. Moffatt SE. Hypothermia in trauma. Emerg Med J 2013;30:989.
37. Soreide E, Smith CE. Hypothermia in trauma victims—friend or foe? Indian J Crit Care Med 2004;8:116.
38. Schmied H, Kurz A, Sessler DI, et al. Mild hypothermia increases blood loss and transfusion requirements during total hip arthroplasty. Lancet 1996;347:289.
39. Kettner SC, Kozek SA, Groetzner JP, et al. Effects of hypothermia on thrombelastography in patients undergoing cardiopulmonary bypass. Br J Anaesth 1998;80:313.
40. Valeri CR, Feingold H, Cassidy G, et al. Hypothermia-induced reversible platelet dysfunction. Ann Surg 1987;205:175.
41. Michelson AD, MacGregor H, Barnard MR, et al. Reversible inhibition of human platelet activation by hypothermia in vivo and in vitro. Thromb Haemost 1994;71:633.
42. Rohrer MJ, Natale AM. Effect of hypothermia on the coagulation cascade. Crit Care Med 1992;20:1402.
43. Sessler DI. Complications and treatment of mild hypothermia. Anesthesiology 2001;95:531.
44. Sessler DI, Schroeder M. Heat loss in humans covered with cotton hospital blankets. Anesth Analg 1993;77:73.
45. Ouellette RG. Comparison of four intraoperative warming devices. AANA J 1993;61:394.
46. Wadhwa A, Komatsu R, Orhan-Sungur M, et al. New circulating-water devices warm more quickly than forced-air in volunteers. Anesth Analg 2007;105:1681.
47. Rein EB, Filtvedt M, Walløe L, et al. Hypothermia during laparotomy can be prevented by locally applied warm water and pulsating negative pressure. Br J Anaesth 2007;98:331.
48. Hynson JM, Sessler DI. Intraoperative warming therapies: a comparison of three devices. J Clin Anesth 1992;4:194.
49. Gendron F. "Burns" occurring during lengthy surgical procedures. J Clin Eng 1980;5:19.

50. Gendron FG. *Unexplained patient burns: investigating iatrogenic injuries*. Wheaton, IL: Quest Publishing Co., Inc; 1988.
51. Sessler DI, Moayeri A. Skin-surface warming: heat flux and central temperature. Anesthesiology 1990;73:218.
52. Janicki PK, Higgins MS, Janssen J, et al. Comparison of two different temperature maintenance strategies during open abdominal surgery upper body forced-air warming versus whole body water garment. Anesthesiology 2001;95:868.
53. Taguchi A, Ratnaraj J, Kabon B, et al. Effects of a circulating-water garment and forced-air warming on body heat content and core temperature. Anesthesiology 2004;100:1058.
54. Hasegawa K, Negishi C, Nakagawa F, et al. Core temperatures during major abdominal surgery in patients warmed with new circulating-water garment, forced-air warming, or carbon-fiber resistive-heating system. J Anesth 2012;26:168.
55. Janicki PK, Stoica C, Chapman WC, et al. Water warming garment versus forced air warming system in prevention of intraoperative hypothermia during liver transplantation: a randomized controlled trial ISRCTN32154832. BMC Anesthesiol 2002;2:7.
56. Gali B, Findlay JY, Plevak DJ. Skin injury with the use of a water warming device. Anesthesiology 2003;98:1509.
57. Cheney FW, Posner KL, Caplan RA, et al. Burns from warming devices in anesthesia. A closed claims analysis. Anesthesiology 1994;80:806.
58. Smith CE, Desai R, Glorioso V, et al. Preventing hypothermia: convective and intravenous fluid warming versus convective warming alone. J Clin Anesth 1998;10:380.
59. Giesbrecht GG, Ducharme MB, McGuire JP. Comparison of forced-air patient warming systems for perioperative use. Anesthesiology 1994;80:671.
60. Bräuer A, English MJM, Steinmetz N, et al. Comparison of forced-air warming systems with upper body blankets using a copper manikin of the human body. Acta Anaesthesiol Scand 2002;46:965.
61. Bräuer A, English MJM, Lorenz N, et al. Comparison of forced-air warming systems with lower body blankets using a copper manikin of the human body. Acta Anaesthesiol Scand 2003;47:58.
62. Krenzischek DA, Frank SM, Kelly S. Forced-air warming versus routine thermal care and core temperature measurement sites. J Post Anesth Nurs 1995;10:69.
63. Steele MT, Nelson MJ, Sessler DI, et al. Forced air speeds rewarming in accidental hypothermia. Ann Emerg Med 1996;27:479.
64. Sessler DI, Schroeder M, Merrifield B, et al. Optimal duration and temperature of prewarming. Anesthesiology 1995;82:674.
65. Fossum S, Hays J, Henson MM. A comparison study on the effects of prewarming patients in the outpatient surgery setting. J Perianesth Nurs 2001;16:187.
66. Andrzejowski J, Hoyle J, Eapen G, et al. Effect of prewarming on postinduction core temperature and the incidence of inadvertent perioperative hypothermia in patients undergoing general anaesthesia. Br J Anaesth 2008;101:627.
67. McGovern PD, Albrecht M, Belani KG, et al. Forced-air warming and ultraclean ventilation do not mix. J Bone Joint Surg Br 2011;93-B:1537.
68. Dasari KB, Albrecht M, Harper M. Effect of forced-air warming on the performance of operating theatre laminar flow ventilation. Anaesthesia 2012;67:244.
69. Tumia N, Ashcroft GP. Convection warmers—a possible source of contamination in laminar airflow operating theatres? J Hosp Infect 2002;52:171.
70. Avidan MS, Jones N, Ing R, et al. Convection warmers—not just hot air. Anaesthesia 1997;52:1073.
71. Albrecht M, Gauthier R, Leaper D. Forced-air warming: a source of airborne contamination in the operating room? Orthop Rev (Pavia) 2009;1:e28.
72. Albrecht M, Gauthier RL, Belani K, et al. Forced-air warming blowers: an evaluation of filtration adequacy and airborne contamination emissions in the operating room. Am J Infect Control 2011;39:321.
73. Sessler DI, Olmsted RN, Kuelpmann R. Forced-air warming does not worsen air quality in laminar flow operating rooms. Anesth Analg 2011;113:1416.
74. Huang JK, Shah EF, Vinodkumar N, et al. The Bair Hugger patient warming system in prolonged vascular surgery: an infection risk? Crit Care 2003;7:R13.
75. Moretti B, Larocca AMV, Napoli C, et al. Active warming systems to maintain perioperative normothermia in hip replacement surgery: a therapeutic aid or a vector of infection? J Hosp Infect 2009;73:58.
76. Sharp RJ, Chesworth T, Fern ED. Do warming blankets increase bacterial counts in the operating field in a laminar-flow theatre? J Bone Joint Surg Br 2002;84:486.
77. Zink RS, Iaizzo PA. Convective warming therapy does not increase the risk of wound contamination in the operating room. Anesth Analg 1993;76:50.
78. Parvizi J, Karam J. *Do forced-air warming blankets increase surgical site infections? Solutions Mcom.* 2013. https://solutions.3m.com/3MContentRetrievalAPI/BlobServlet?lmd=1341678838000&assetId=1319232696612&assetType=MMM_Image&blobAttribute=ImageFile [accessed 06.07.16].
79. Lidwell OM. Air, antibiotics and sepsis in replacement joints. J Hosp Infect 1988;11:18.
80. Whyte W. The role of clothing and drapes in the operating room. J Hosp Infect 1988;11:2.
81. Noble WC. Dispersal of skin microorganisms. Br J Dermatol 1975;93:477.
82. Siddik-Sayyid SM, Saasouh WA, Mallat CE, et al. Thermal burn following combined use of forced air and fluid warming devices. Anaesthesia 2010;65:654. discussion 655-6.
83. Chung K, Lee S, Oh S-C, et al. Thermal burn injury associated with a forced-air warming device. Korean J Anesthesiol 2012;62:391.
84. Uzun G, Mutluoglu M, Evinc R, et al. Severe burn injury associated with misuse of forced-air warming device. J Anesth 2010;24:980.
85. Azzam FJ, Krock JL. Thermal burns in two infants associated with a forced air warming system. Anesth Analg 1995;81:661.
86. Stewart C, Harban F. Thermal injuries from the use of a forced-air warming device. Pediatr Anesth 2012;22:414.
87. Truell KD, Bakerman PR, Teodori MF, et al. Third-degree burns due to intraoperative use of a Bair Hugger warming device. Ann Thorac Surg 2000;69:1933.
88. Camus Y, Delva E, Just B, et al. Leg warming minimizes core hypothermia during abdominal surgery. Anesth Analg 1993;77:995.
89. Greif R, Rajek A, Laciny S, et al. Resistive heating is a more effective treatment for accidental hypothermia than metallic-foil insulators. Eur J Anaesthesiol 2000;17:175.
90. Kober A, Scheck T, FüLesdi B, et al. Effectiveness of resistive heating compared with passive warming in treating hypothermia associated with minor trauma: a randomized trial. Mayo Clin Proc 2001;76:369.
91. Camus Y, Delva E, Bossard AE, et al. Prevention of hypothermia by cutaneous warming with new electric blankets during abdominal surgery. Br J Anaesth 1997;79:796.
92. Matsuzaki Y, Matsukawa T, Ohki K, et al. Warming by resistive heating maintains perioperative normothermia as well as forced air heating. Br J Anaesth 2003;90:689.
93. Negishi C, Hasegawa K, Mukai S, et al. Resistive-heating and forced-air warming are comparably effective. Anesth Analg 2003;96:1683.
94. Egan C, Bernstein E, Reddy D, et al. A randomized comparison of intraoperative PerfecTemp and forced-air warming during open abdominal surgery. Anesth Analg 2011;113:1076.
95. Brandt S, Oguz R, Hüttner H, et al. Resistive-polymer versus forced-air warming: comparable efficacy in orthopedic patients. Anesth Analg 2010;110:834.
96. Fanelli A, Danelli G, Ghisi D, et al. The efficacy of a resistive heating underpatient blanket versus a forced-air warming system: a randomized controlled trial. Anesth Analg 2009;108:199.
97. Ng V, Lai A, Ho V. Comparison of forced-air warming and electric heating pad for maintenance of body temperature during total knee replacement. Anaesthesia 2006;61:1100.
98. Leung KK, Lai A, Wu A. A randomised controlled trial of the electric heating pad vs forced-air warming for preventing hypothermia during laparotomy. Anaesthesia 2007;62:605.
99. Röder G, Sessler DI, Roth G, et al. Intra-operative rewarming with Hot Dog® resistive heating and forced-air heating: a trial of lower-body warming. Anaesthesia 2011;66:667.
100. Engelen S, Himpe D, Borms S, et al. An evaluation of underbody forced-air and resistive heating during hypothermic, on-pump cardiac surgery. Anaesthesia 2011;66:104.
101. Horn EP, Bein B, Böhm R, et al. The effect of short time periods of preoperative warming in the prevention of peri-operative hypothermia. Anaesthesia 2012;67:612.
102. Dewar DJ, Fraser JF, Choo KL, et al. Thermal injuries in three children caused by an electrical warming mattress. Br J Anaesth 2004;93:586.
103. Plattner O, Ikeda T, Sessler DI, et al. Postanesthetic vasoconstriction slows peripheral-to-core transfer of cutaneous heat, thereby isolating the core thermal compartment. Anesth Analg 1997;85:899.
104. Mathur A, Grahn D, Dillingham MF, et al. Treatment of mild hypothermia using the "Thermo-STAT (TM)" facilitates earlier discharge from the post anesthesia care unit. Anesthesiology 1999;91:U480.
105. Grahn D, Brock-Utne JG, Watenpaugh DE, et al. Recovery from mild hypothermia can be accelerated by mechanically distending blood vessels in the hand. J Appl Physiol 1998;85:1643.
106. Smith CE, Parand A, Pinchak AC, et al. The failure of negative pressure rewarming (Thermostat) to accelerate recovery from mild hypothermia in postoperative surgical patients. Anesth Analg 1999;89:1541.
107. Taguchi A, Arkilic CF, Ahluwalia A, et al. Negative pressure rewarming vs. forced air warming in hypothermic postanesthetic volunteers. Anesth Analg 2001;92:261.
108. Sessler D. Consequences and treatment of perioperative hypothermia. Anesthesiol Clin North Am 1994;12:425.
109. Stone DR, Downs JB, Paul WL, et al. Adult body temperature and heated humidification of anesthetic gases during general anesthesia. Anesth Analg 1981;60:736.
110. Kaufman RD. Relationship between esophageal temperature gradient and heart and lung sounds heard by esophageal stethoscope. Anesth Analg 1987;66:1046.
111. Bissonnette B, Sessler DI. Passive or active inspired gas humidification increases thermal steady-state temperatures in anesthetized infants. Anesth Analg 1989;69:783.
112. Winkler M, Akça O, Birkenberg B, et al. Aggressive warming reduces blood loss during hip arthroplasty. Anesth Analg 2000;91:978.

113. Casati A, Fanelli G, Ricci A, et al. Shortening the discharging time after total hip replacement under combined spinal/epidural anesthesia by actively warming the patient during surgery. Minerva Anestesiol 1999;65:507.
114. Bennett J, Ramachandra V, Webster J, et al. Prevention of hypothermia during hip surgery: effect of passive compared with active skin surface warming. Br J Anaesth 1994;73:180.
115. Frisch NB, Pepper AM, Jildeh TR, et al. Intraoperative hypothermia during surgical fixation of hip fractures. Orthopedics 2016;39:e1170.
116. Leijtens B, Koëter M, Kremers K, et al. High incidence of postoperative hypothermia in total knee and total hip arthroplasty. J Arthroplasty 2013;28:895.
117. Benson EE, McMillan DE, Ong B. The effects of active warming on patient temperature and pain after total knee arthroplasty. Am J Nurs 2012;112:26. quiz 34, 42.
118. Brown C. Maintaining intraoperative normothermia: a meta-analysis of outcomes with costs. AANA J 1999;67:155.

EXHIBIT DX24

TO DECLARATION OF BENJAMIN W. HULSE IN SUPPORT OF DEFENDANTS' MOTION TO EXCLUDE PLAINTIFFS' GENERAL CAUSATION MEDICAL EXPERTS

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

STATE OF MINNESOTA

COUNTY OF RAMSEY

DISTRICT COURT

SECOND JUDICIAL DISTRICT

CIVIL COURT

In Re: 3M Bair Hugger Litigation

Court File Number: 62-CV-15-6432

ORDER 10

Assigned Judge: William H. Leary III

This matter came before the undersigned Judge of the District Court on May 18, 2017, for a joint hearing before this court and the United States District Court – Minnesota on Plaintiffs' Motion for Leave to Amend Master Long Form and Short Form Complaints to Add Claim for Punitive Damages.

The appearances are those noted at the time of the hearing.

The parties were directed to provide proposed orders by June 1, 2017, after which the matter was taken under advisement.

This court, having in mind the arguments of counsel, the applicable law, and all files and records herein, issues the following order.

IT IS ORDERED that Plaintiffs' Motion for Leave to Amend Master Long Form and Short Form Complaints to Add Claim for Punitive Damages is **DENIED**.

The accompanying memorandum is incorporated herein by reference.

August 18, 2017

William H. Leary III
Judge of District Court

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

MEMORANDUM

1. Plaintiffs' and Defendants' liaison counsel agreed to submit Plaintiffs' Motion for Leave to Amend Master Long Form and Short Form Complaints to Add Claim for Punitive Damages in a single hearing before a joint session of the United States District Court and the Ramsey County District Court.

2. At the conclusion of the hearing on Plaintiffs' motion, the undersigned directed the parties to submit proposed orders for this court's consideration. The proposed orders were filed on June 1, 2017, at which time the court took the matter under advisement.

3. Each party's proposed order represents the party's view of the evidence and law to be applied. This court has carefully considered the record presented, the arguments of counsel, the applicable law, and the proposed orders. To the extent that this order adopts the analysis and language of a party's proposed order, this court has determined that they accurately reflect the evidence and applicable law.

I. Relevant Legal Standards

4. "Punitive damages are not generally favored by the law." *Lewis v. Equitable Life Assurance Soc'y of the United States*, 389 N.W.2d 876, 892 (Minn. 1986).

5. Minnesota law prohibits a plaintiff from seeking punitive damages unless the plaintiff is first able to satisfy the preliminary evidentiary burden set forth in Minnesota Statute Section 549.191. *McKenzie v. Northern States Power Co.*, 440 N.W.2d 183, 184 (Minn. Ct. App. 1989) (Minn. Stat. § 549.191 "creates a preliminary evidentiary burden which plaintiff must meet before he may plead punitive damages") (*quoting Fournier v. Marigold Foods, Inc.*, 678 F. Supp. 1420, 1422 (D. Minn. 1988)).

6. Thus, the purpose of section 549.191 is to ensure that punitive damages are only pleaded in those cases where such damages are appropriate. *Bougie v. Sibley Manor, Inc.*, 504 N.W.2d 493, 499 (Minn. App. 1993). The statute "serves a fundamental gatekeeping function which rids the courts of unfounded, or of abusive, punitive damage claims." *Backlund v. City of Duluth*, 176 F.R.D. 316, 320 (D. Minn. 1997); *see also Ulrich v. City of Crosby*, 848 F. Supp. 861, 867 (D. Minn. 1994) (Minnesota Statute Section 549.191 was adopted "in order to deter certain practices in the presentment of punitive damage claims which were thought to be abusive"); *Gamma-10 Plastics, Inc. v. Am. President Lines, Ltd.*, 32 F.3d 1244, 1255 (8th Cir. 1994) (policy underlying Minnesota Statute Section 549.191 "was enacted to prevent frivolous punitive damage claims by allowing a court to determine first if punitive damages are appropriate").

A. Plaintiffs' Burden: Clear and Convincing Evidence of Deliberate Disregard of a High Probability of Injury.

7. Under Minnesota substantive punitive damages standard, set forth in Minnesota Statute Section 549.20, a plaintiff must present clear and convincing evidence that a defendant

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

acted with deliberate disregard of a high probability of injury before the plaintiff can assert a claim for punitive damages:

> (a) Punitive damages shall be allowed in civil actions only upon clear and convincing evidence that the acts of the defendant show deliberate disregard for the rights or safety of others.
>
> (b) A defendant has acted with deliberate disregard for the rights or safety of others if the defendant has knowledge of facts or intentionally disregards facts that create a high probability of injury to the rights or safety of others and:
>
> (1) deliberately proceeds to act in conscious or intentional disregard of the high degree of probability of injury to the rights or safety of others; or
>
> (2) deliberately proceeds to act with indifference to the high probability of injury to the rights or safety of others.

Id.; *see also Bunker v. Meshbesher*, 147 F.3d 691, 696 (8th Cir. 1998) (the "clear and convincing standard of proof is implicitly incorporated" into the requirement that Plaintiffs establish a *prima facie* case of deliberate disregard); *Gamma-10*, 32 F.3d at 1254-55 ("In Minnesota, a plaintiff makes a prima facie case for punitive damages by establishing 'clear and convincing evidence that the acts of the defendant show deliberate disregard for the rights or safety of others.'"); *McKenzie*, 440 N.W.2d at 184 ("[T]he trial court must consider the elements and burden of proof required to recover punitive damages when deciding whether prima facie evidence has been submitted and ruling on a motion to amend.").

8. "[T]he mere existence of negligence or of gross negligence does not rise to the level of willful indifference so as to warrant a claim for punitive damages." *Ulrich*, 848 F. Supp. at 868 (D. Minn. 1994); *see also Admiral Merchants Motor Freight, Inc. v. O'Connor & Hannan*, 494 N.W.2d 261, 268 (Minn. 1992) ("A mere showing of negligence is not sufficient; instead, the conduct must be done with malicious, willful, or reckless disregard for the rights of others."); *McCloud v. Norwest Bank Minn., N.A.*, No. C4-96-601, 1996 WL 509846, at *5 (Minn. Ct. App. Sept. 10, 1996) ("Evidence of negligence or gross negligence does not warrant a claim for punitive damages."); *McKenzie*, 440 N.W.2d at 184 ("mere indifference to others is insufficient and plaintiff must establish maliciousness by intentional or willful failure to act despite knowledge of danger to others") (*citing Wikert v. Northern Sand & Gravel, Inc.*, 402 N.W.2d 178, 182-83 (Minn. Ct. App. 1987)).

B. The Court Must Focus on the Evidence Presented, Not Plaintiffs' Allegations or Characterization of the Evidence.

9. When presented with a motion to permit assertion of a punitive damage claim, the function of the trial court is to do more than "rubber stamp" the allegations in the motion papers. *Shetka v. Kueppers, Kueppers, Von Feldt & Salmen*, 454 N.W.2d 916, 918 n.1 (Minn. 1990).

10. In determining whether Plaintiffs have met their burden, the court cannot rely on Plaintiffs' arguments, nor upon Plaintiffs' construction of documents, speculation or conclusory comment. The court must "carefully scrutinize" the evidence apart from Plaintiffs' advocacy. *See id.* at 1011-12 (counsel's construction of documents "'infused with his robust advocacy, as supplemented by a liberal use of surmise, conjecture and conclusory comment" is insufficient to support a motion for leave to assert a punitive damage claim); *Berczyk v. Emerson Tool Co.*, 291 F. Supp. 2d 1004, 1012 n. 7 (D. Minn. 2003) (denying leave to seek punitive damages where "[t]he degree of deviation, between the Affiant's summarization of the referenced documents, and the content of the documents, is frequently considerable."); *Target Corp. v. LCH Pavement Consultants, LLC*, 960 F. Supp. 2d 999 (D. Minn. 2013) ("[T]he Court must carefully scrutinize the evidence presented by the moving party to make sure that it amounts to a prima facie showing that the substantive requirements for punitive damages have been met.").

C. The Court May Consider Only Competent and Relevant Evidence.

11. Not all material submitted by a plaintiff may be considered by the court. A motion for leave to assert a punitive damages claim must be based upon competent, admissible evidence. *Berczyk*, 291 F. Supp. 2d at 1010 ("'Quite plainly, a 'prima facie case,' established by 'clear and convincing' evidence, requires evidence that is both competent, and probative, that is, the evidence must be admissible.").

12. Evidence that is circumstantial, or that could be construed as demonstrating "mere indifference" to the plaintiff's rights, is insufficient to satisfy the plaintiff's evidentiary burden and a motion based on such evidence should be denied. *Gamma-10*, 32 F.3d at 1255 (motion to amend denied where plaintiff provided "at best only circumstantial evidence that [defendant] acted recklessly, willfully, deliberately or with gross disregard for [plaintiff's] rights" and where alleged misconduct could have been committed, instead, with mere indifference to plaintiff's rights). Similarly, a claim for punitive damages is inappropriate where the evidence presented allows for the conclusion that the defendant acted in good faith. *Peterson v. Sorlien*, 299 N.W.2d 123, 129 (Minn. 1980) ("Good faith is a proper defense to punitive damages, even though defendants might have been mistaken in their belief that a party was in jeopardy or that their decisions were correct.").

13. The court may not consider unsworn expert reports or statements under Minn. Stat. § 549.191. *Healey v. I-Flow LLC*, 853 F. Supp. 2d 868, 881 (D. Minn. 2012).

14. A plaintiff also may not rely on evidence of alleged misconduct that is unrelated to the underlying claims for relief or that relates to a claim for which punitive damages are inappropriate. *See State Farm Mutual Automobile Ins. Co. v. Campbell*, 538 U.S. 408, 422-23 (2003) (a claim for punitive damages may not be based upon conduct that bears no relationship to the plaintiff's harm); *see also Rosenbloom v. Flygare*, 501 N.W.2d 597, 601 (Minn. 1993) (trial court erred by permitting jury to consider evidence of racial discrimination in awarding punitive damages because such evidence was not relevant to the claim for which punitive damages could be awarded).

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

D. Limitations on Conduct that May Be Imputed to a Corporation.

15. Minnesota Statute Section 549.20 also strictly limits the conduct that may be imputed to a corporate defendant in determining whether the punitive damages standard has been met. Acts may be imputed only if done by a person "employed in a managerial capacity with authority to establish policy and make planning level decisions" or if a person with such authority "ratified or approved" the statements. Minn. Stat. § 549.20, subd. 2(3), (4). The court cannot consider employee statements as evidence to support Plaintiffs' *prima facie* showing unless they satisfy the statutory managerial authority test. *See Baufield v. Safelite Glass Corp.*, 829 F. Supp. 285, 286 (D. Minn. 1993) (granting judgment as a matter of law to defendant as to plaintiff's claim for punitive damages where plaintiff failed to satisfy the statute's managerial authority test); *DOE YZ v. Shattuck-St. Mary's School*, No. 15-1151, 2016 WL 5858641, at *22 (D. Minn. Oct. 5, 2016) (denying leave to amend to allege punitive damages: "While [knowledge of nonmanagerial employees] is imputable to [the corporation] for negligence purposes, it is not imputable to [the corporation] for assessing punitive liability.").

E. The Court May Apply the Evidentiary Rule of Completeness to Provide Context and Guarantee Fairness.

16. While the Court may not consider pure rebuttal evidence in evaluating a motion under Minn. Stat. § 549.19, Minnesota law nonetheless permits, and may even require, the court to consider other relevant portions of the documents or testimony to ensure fundamental fairness. Put another way, the Court is not required to – and should not – consider only the line or page of a document highlighted by Plaintiffs, when the next line or page provides important context. *See Berczyk*, 291 F. Supp. 2d at 1013-14 (finding that "snippets" from various documents "appended" to each other cannot satisfy the plaintiffs' burden).

17. Furthermore, Rule 106 of the Minnesota Rules of Evidence provides that "[w]hen a writing or recorded statement or part thereof is introduced by a party, an adverse party may require the introduction at that time of any other part or any other writing or recorded statement which ought in fairness to be considered *contemporaneously* with it." *State v. Robledo-Kinney*, 615 N.W.2d 25, 29 (Minn. 2000) (emphasis added). "The rule is based on concepts of fairness and encourages the trial judge to require the admission of all relevant portions of a document when a party attempts to use selected portions." 11 Minn. Prac., Evidence § 106.01 (4th ed. 2016). "The rationale is to insure that the offer of evidence is placed in proper context so that the jury is not incurably prejudiced by the use of selective parts of an equivocal document. To wait until the adverse party can introduce the other portions of the document in the adverse party's case is an inadequate response to the problem." *Id.*; *see also State v. Brodt*, 150 Minn. 431, 185 N.W. 645, 647 (1921) ("When the significance of a former statement of a witness has been distorted by a fragmentary or inaccurate repetition of it, the entire conversation or writing may be received to explain its true significance"). Thus, this court may consider other excerpts of the same documents and depositions offered by Plaintiffs to ensure that it understands the full context and to guarantee fundamental fairness. This Court's decision to deny Plaintiffs' motion still would be the same, however, even if it considered only Plaintiffs' submissions.

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

II. Choice of Law

18. The amendment procedure of Minn. Stat. § 549.191 is procedural and applies to all plaintiffs with Bair Hugger lawsuits pending in Ramsey County.

19. The legal standard for recovering punitive damages is substantive, however, and requires a choice-of-law analysis. *See Healey* at 874 ("[I]f the applicable punitive damages law does not allow punitive damages for the type of claim at issue, then of course the plaintiff could not meet section 549.191 requirements because the moving party could not make out a prima facie showing of entitlement to punitive damages.").

20. While there has been only limited, case-specific discovery to date, the parties concur that Minnesota substantive law is likely to apply to cases brought by Minnesota residents who allege that they developed surgical site infections after a medical procedure that occurred in Minnesota. Based on information presently available to the parties, those cases are as follows:

Case Number	Title	Current State of Residency	Residency at Time of Surgery	Surgery Location
62-cv-15-4748	Sehnert	Minnesota	Minnesota	Minnesota
62-cv-16-3236	Schweim	Minnesota	Minnesota	Minnesota
62-cv-15-6477	Wohl	Minnesota	Minnesota	Minnesota
62-cv-15-7356	Ayotte	Minnesota	Minnesota	Minnesota
62-cv-15-7364	Duquette	Minnesota	Minnesota	Minnesota
62-cv-15-7363	Duvernay	Minnesota	Minnesota	Minnesota
62-cv-15-7362	Enskat	Minnesota	Minnesota	Minnesota
62-cv-16-161	Olson	Minnesota	Minnesota	Minnesota
62-cv-16-547	Rome	Minnesota	Minnesota	Minnesota
62-cv-16-2181	Stevens	Minnesota	Minnesota	Minnesota
62-cv-16-1777	Walker	Minnesota	Minnesota	Minnesota

62-cv-16-3861	Gilmor	Minnesota	Minnesota	Minnesota
62-cv-16-3860	Logan	Minnesota	Unknown	Minnesota
62-cv-16-3950	Pillsbury	Minnesota	Minnesota	Minnesota
62-cv-16-4289	Racine	Minnesota	Minnesota	Minnesota
62-cv-15-6848	Reding	Minnesota	Minnesota	Minnesota
62-cv-17-138	Kelly	Minnesota	Minnesota	Minnesota
62-cv-17-136	Walgren	Minnesota	Minnesota	Minnesota
62-cv-17-727	Foster	Minnesota	Minnesota	Minnesota
62-cv-17-763	Sylvester	Minnesota	Minnesota	Minnesota
62-cv-17-2261	Barber	Minnesota	Minnesota	Minnesota
62-cv-17-2263	Hartman	Minnesota	Minnesota	Minnesota

Because little case-specific discovery has been had at this time, the court does not foreclose the parties from arguing at a later stage of proceedings that a different state's law applies to any of these cases based upon facts subsequently developed.

21. In tort cases involving personal injuries, Minnesota law presumptively does not apply to plaintiffs who are not Minnesota residents and did not receive medical care in Minnesota. *See Schmelzle v. Alza Corp.*, 561 F. Supp. 2d 1046, 1050 (D. Minn. 2008) ("Minnesota's interest in compensating tort victims is lessened where the injury occurred in another state, the injured party is not a Minnesota resident and did not receive medical care here."); *In re Baycol Prods. Litig.*, 218 F.R.D. 197, 207 (D. Minn. 2003) (maintenance of interstate order weighs in favor of applying the law of the state in which the plaintiff resides and where the drug was prescribed). Plaintiffs' motion is limited to an analysis of the substantive standard for recovery of punitive damages under Minnesota law. Plaintiffs have made no attempt to demonstrate that they are entitled to punitive damages under the substantive law of any state other than Minnesota.

III. Plaintiffs' Evidence as to Minn. Stat. § 549.20.

22. Plaintiffs' evidence fails to satisfy their burden to present clear and convincing evidence that either Defendant deliberately disregarded a high probability of injury, as required by Minn. Stat. § 549.20.

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

A. Plaintiffs' Cited Articles Disclaim Any Conclusion that the Bair Hugger System Causes Surgical Site Infections.

23. As noted one of the studies submitted by Plaintiffs with their motion, forced-air warming, the type of patient warming technology employed by the Bair Hugger system, "is widely used to prevent surgical hypothermia. The benefits of preventing surgical hypothermia include reduced blood loss, improved wound healing, reduced duration of hospital stay, improved survival, and reduced rates of surgical site infections." (PX38, Reed et al., at 1.[1]) *See In re Prempro Prods. Liab. Litig.*, 586 F.3d 547, 572 (8th Cir. 2009) (affirming judgment as a matter of law for Upjohn with respect to punitive damages, despite its violation of federal drug marketing regulations, because "there is no dispute that prescribing [Upjohn's product] along with estrogen had become the standard of care in hormone replacement theory").

24. As noted in another of the studies submitted by Plaintiffs, patient warming is the standard of surgical care: "Patient warming is a recognized and necessary standard of surgical care, with warmed patients having better outcomes through reduced blood loss, improved wound healing, reduced duration of hospital stay, improved survival, and reduced surgical site infection rates for 'dirty' (colorectal) surgery." (PX37, Belani et al., at 1.)

25. Plaintiffs' core contention is that the Bair Hugger system presents a high probability of injury to patients by causing increased surgical site infections. But Plaintiffs present no evidence that any scientific study – including those studies relied upon by Plaintiffs and their experts – has ever concluded that the Bair Hugger patient warming system causes increased surgical site infections.

26. Plaintiffs cite eight studies published between 2009 and 2013. (Pl. Mem. 24-28.) Nearly all of these studies were either co-authored by an employee of Defendants' competitor and longtime antagonist, Scott Augustine (Mark Albrecht, listed as a co-author of PX29, PX30, PX33, PX35, PX37, PX38), and/or indicate that they were sponsored by Augustine (PX33 at p. 1544; PX35 at 248; PX37 at p. 5). Even so, not one of these studies concludes that the Bair Hugger system causes surgical site infections. To the contrary, each study expressly disclaims such a conclusion:

Publication	Language Disclaiming Conclusion that Bair Hugger Warming Blanket Increases Risk
Albrecht M et al., Forced-air warming: a source of airborne contamination in the operating room? *Orthopedic Rev.* 2009; 1(2):e28 (PX29)	"[T]he present study did not evaluate the link between forced air warming and surgical site infection rates …"
Albrecht M et al., Forced-air warming blowers: An evaluation	"[O]ur findings do not establish a direct link between forced air warming and increased

[1] "PX" refers to exhibits submitted in support of Plaintiffs' Motion. "DX" refers to exhibits submitted by Defendants.

of filtration adequacy and airborne contamination emissions in the operating room. *Am J Infect Control* 2010; 39:321-28 (PX30)	surgical site infection rates …"
McGovern PD et al., Forced-air warming and ultra-clean ventilation do not mix. *J Bone & Joint Surg-Br*. 2011; 93-B(1 l):1537-44 (PX33)	"This study does not establish a causal basis for this association [the patient warming device and the risks of surgical site infections in the study]."
Legg A et al., Do forced air patient-warming devices disrupt unidirectional downward airflow? *J Bone & Joint Surg-Br*. 2012; 94-B:254-6 (PX34) [2]	"Because of the nature of our experiment we are unable to conclude that the use of the forced air warming device … would actually lead to an increased risk of surgical site infection."
Dasari KR et al., Effect of forced air warming on the performance of operating theatre laminar flow ventilation. *Anaesthesia* 2012; 67:244-49 (PX35)	"Another limitation of our study is that the definitive effects of this excess heat on clinical outcomes is presently unknown."
Legg A et al., Forced-air patient warming blankets disrupt unidirectional airflow. *Bone Joint J*. 2013 Mar; 95-B(3):407-10 (PX36)	"This study does not show that forced-air warming increases the risk of infection …"
Reed M et al., Forced-air warming design: evaluation of intake filtration, internal microbial buildup, and airborne-contamination emissions. AANA J. 2013 Aug; 81(4):275-80 (PX38)	"Last, we did not track hospital infections, nor did we study the association between FAW [forced-air warming] contamination generation/emission and hospital infection rates …"
Belani K et al., Patient warming excess heat: The effects on orthopedic operating room ventilation performance. *Anesthesia &Analgesia* 2012 (prepublication on-line) 2013; 117(2):406-411 (PX37)	"Thus, we are unsure of the exact degree of ventilation disruption that might occur in a working OR during orthopedic surgery… future research is warranted to characterize the clinical conditions under which forced air warming excess heat results in ventilation disruption during surgery."

This is not rebuttal evidence; this is Plaintiffs' own evidence. In fact, Plaintiffs contend nothing more than that these articles "raised questions" about an increased risk of surgical site infections. (Pl. Proposed Order 16.) Given the articles' disclaimers, underscored by Plaintiffs' modest

[2] Plaintiffs assert that Defendants "attempted to coerce" the *Journal of Bone & Joint Surgery* to retract the 2012 Legg study. (Pl. Mem. 42.) They offer no evidence to support their allegation. Plaintiffs present no evidence that Defendants ever contacted Legg, his co-authors, or the editor.

contention, these studies are not clear and convincing evidence of either a high probability of injury, much less Defendants' deliberate disregard of a high probability of injury.

27. Consistent with the scientific literature, Plaintiffs present no evidence that there has ever been an FDA recall of the Bair Hugger system related to infection (or otherwise). Plaintiffs also present no evidence that the FDA has issued any safety communication, warning letter, or taken any other enforcement action related to an infection. *Compare In re Levaquin Prods. Liab. Litig*, No. 08-5743, 2010 WL 7852346, at *2 (D. Minn. Nov. 9, 2010) ("several European regulatory authorities decided to take corrective action" based on a series of studies associating levofloxacin use with higher rates of tendon disorders).

28. While it is undisputed that surgeries have been conducted using the Bair Hugger system for more than 25 years, Plaintiffs present no evidence that any doctor has ever reported to 3M or Arizant that the Bair Hugger system caused his or her patient to develop a surgical site infection. The facts here are like those in *Healey*, where the court denied the motion for leave to allege punitive damages. In *Healey*, the plaintiff likewise submitted no evidence that a physician ever informed the defendant that the defendant's medical device had caused his injury. 853 F. Supp. 2d at 877-81. This litigation is also similar to *Mack v. Stryker Corp.*, No. 10-2993 (PAM/JJG), 2012 WL 12896248 (D. Minn. Feb. 28, 2012). There, the court denied leave to amend where there were no reports from doctors of injuries caused by use of Stryker's device prior to the plaintiff's surgery. *Id.* at *4-5.

29. Neither party has identified any case where a court applying Minnesota law has permitted leave to amend to allege punitive damages in similar circumstances: where the defendant's medical device remains the standard of care; its significant benefits to patient health and safety are undisputed; there has been no FDA action or warning; no doctor has complained that the defendant's product caused any injury; and there is no scientific study concluding that the defendant's product causes injuries.

IV. The Arguments in Plaintiffs' Expert Reports Are Not Proof that Defendants Deliberately Disregarded Scientific Proof that the Bair Hugger System Causes Surgical Site Infections.

30. Notwithstanding the disclaimers in the articles relied upon by Plaintiffs, Plaintiffs argue they should be permitted to pursue punitive damages based on the conclusions in reports from two of their retained experts, Drs. Samet and Jarvis. Samet and Jarvis provide causation opinions that the authors of the studies cited by Plaintiffs all declined to reach.

31. As a threshold evidentiary matter, the court may not consider Samet's and Jarvis's reports in determining whether Plaintiffs have met the requirements of Minn. Stat. § 549.191 (which, as explained *supra*, applies regardless of choice of law). As the *Healey* court concluded in refusing to consider plaintiffs' expert reports, an expert report that is not in the form of a sworn affidavit does not satisfy Minn. Stat. § 549.191's requirement that a motion for leave to amend to allege punitive damages be accompanied by affidavits showing the factual basis for the claim. *Healey*, 853 F. Supp. 2d at 881. That the expert reports are attached to the declaration of Plaintiffs' counsel does not make them proper under Minn. Stat. § 549.191.

32. Even if they were procedurally proper, Samet's and Jarvis's reports suffer from the same defect that the plaintiffs' expert reports suffered from in *Healey*. Like Dr. Trippel in *Healey*, Samet and Jarvis did not conduct their own studies, but instead relied upon the same eight studies that Plaintiffs have cited – all of which disclaim the conclusion that the Bair Hugger system causes surgical site infections. *Healey*, 853 F. Supp. 2d at 881-82 (Trippel's review of the medical literature was not clear and convincing evidence). For the purposes of a motion to amend to allege punitive damages, an expert's opinion cannot spin straw into gold – it cannot satisfy the "clear and convincing" standard when the underlying scientific literature does not satisfy that standard. *See Berczyk*, 291 F. Supp. 2d at 1015-16 (expert report submitted in support of punitive damages was "predicated on many of the same documents that we found to be an inadequate basis on which to establish a claim of deliberate disregard").

33. The problem is illustrated by Samet's conclusions that the McGovern 2011 study demonstrates an "elevated 3.8 risk ratio" and therefore "the Bair Hugger device would constitute a substantial contributing cause" of infections. (PX E at 16.) On its face, the McGovern study does not support this conclusion. The study looked at infection rates at a hospital in the United Kingdom during a period when the Bair Hugger system was in use versus a period when competitor Augustine's HotDog device was in use. McGovern and his co-authors (including Mark Albrecht, an employee of competitor Augustine) noted that their study was not controlled and that several confounding factors could explain the results:

> Although the demographics were similar between the patient groups in terms of risk factors for infection, the data are observational and may be confounded by other infection control measures instituted by the hospital. For example, changes were made to the antibiotic and thromboprophylaxis protocols used during the study, although no infection control changes were made after February 2010.
>
> In addition, we were unable to consider all factors that have been associated with SSI, as the details of blood transfusion, obesity, incontinence and fitness for surgery, which have been identified elsewhere as important predictors for deep infection, were not sufficiently detailed in the medical record.

(PX33 at p. 1543.) Plainly, changes in the antibiotic regimen during the study could be highly relevant to rates of infection.

34. That Samet's and Jarvis's unsworn reports cannot be "clear and convincing" evidence is underscored by another document offered by Plaintiffs. Plaintiffs have submitted excerpts of the 2013 Proceedings of the International Consensus Meeting on Periprosthetic Joint Infection, but have excised portions of the Proceedings that directly undercut their experts' conclusions. (PX4.) As previously discussed, this court may consider other portions of this document under Rule 106 of the Minnesota Rules of Evidence. The Proceedings reflect the "cumulative wisdom of over 400 of the world's experts in musculoskeletal infection from 52 countries." (DX18 at 4.) The group reached a "strong consensus" in 2013 as follows: "We recognize the theoretical risk posed by FAW [forced air warming] blankets and that no studies

have shown an increase in SSI [surgical site infections] related to the use of these devices. We recommend further study but no change to current practice." (*Id.* at 5.) Eighty-nine percent of delegates voted in support of the statement while only five percent voted against and six percent disagreed. The discussion and notes indicate that the delegates considered and evaluated the same studies relied upon by Samet and Jarvis, including McGovern. (*Id.*)

35. Defendants' rejection of a viewpoint supported by just 5 percent of an assembly of more than 400 experts in the field of musculoskeletal infection falls far short of clear and convincing evidence of a deliberate disregard of a high probability of injury.

36. Separately, Plaintiffs also rely upon "testing" in a laboratory clean room by one of their retained experts, Michael Buck, and a computer model created by another of their retained experts, Said Elghobashi. (Pl. Mem. 8-10.) Based on those experts' conclusions, Plaintiffs argue: "If Defendants had performed proper validation testing prior to marketing the Bair Hugger, they would have found" that air from the Bair Hugger blower increased the amount test particles around the surgical site. (*Id.*) Such an argument is a long way from demonstrating a high probability of injury from an increased rate of infection.

B. Plaintiffs' Allegation that Arizant and 3M Failed to Validate the Safety of the Bair Hugger System Is Contradicted by Plaintiffs' Own Evidence.

37. Plaintiffs further argue that Arizant and 3M "failed to validate the safety of the Bair Hugger system" before the Bair Hugger system was used in Plaintiffs' surgeries. (Pl. Mem. 5.) Plaintiffs cite to several scientific studies focused on the safety of the Bair Hugger system, studies that preceded the use of Bair Hugger systems in most, if not all, of Plaintiffs' surgeries. (Pl. Mem. 30-32.)

38. First, Plaintiffs concede that in 1993 *Anesthesia & Analgesia* published a study by Zink et al. entitled "Convective warming therapy does not increase the risk of wound contamination in the operating room," which concluded exactly what the title says. (DX6). Plaintiffs concede that the study involved Bair Hugger system. This study was published many years before the use of the Bair Hugger system in the surgery of any of the plaintiffs in the MDL.

39. Second, Plaintiffs concede that in 2003 *Critical Care* published a study in which the authors took bacterial cultures at the start and finish of surgery with the use of a Bair Hugger system. (DX7.) The study concluded that "there was no increase in air contamination associated with the Bair Hugger patient warming system."

40. Third, Plaintiffs concede that in 2009 the *Journal of Hospital Infection* published a study by Moretti et al. in which the authors took cultures with and without the use of the Bair Hugger system. The authors concluded: "Statistical analysis of the results demonstrated that the Bair Hugger system does not pose a real risk for nosocomial infections, whereas it does offer the advantage of preventing the potentially severe consequences of hypothermia during major orthopaedic surgery." (DX8.)

41. The studies submitted by Plaintiffs also reference other studies supporting the safety of the Bair Hugger system that predate all or most of Plaintiffs' surgeries. For example,

McGovern and his co-authors cite Kurz et al., "Perioperative normothermia to reduce the incidence of surgical-wound infection and shorten hospitalization: study of wound infection and temperature group," published in the *New England Journal of Medicine* in 1996. (PX33 at p. 1544.)

42. Even if Plaintiffs were correct that the Bair Hugger system never went through safety testing prior to their surgeries, that assumption would provide no support for their motion. There is no dispute that the Bair Hugger system is a 510(k) device cleared by the FDA. As the *Healey* court concluded, a medical device manufacturer's failure to conduct safety and effectiveness testing of a 510(k) device, when the FDA has not required it, is not *prima facie* evidence to support punitive damages. *Healey*, 853 F. Supp. 2d at 879; *see also Mack*, 2012 WL 12896248, at *4 (denying motion for leave to seek punitive damages; Stryker's failure to conduct safety testing of its pain pump was not clear and convincing evidence because 21 C.F.R. § 807.92 did not require safety and effectiveness testing of the device).

C. Plaintiffs' Corporate Documents and Deposition Excerpts.

43. The remainder of Plaintiffs' argument is based heavily on excerpts taken from Arizant and 3M corporate documents generated over a period of nearly 30 years. For the most part, these isolated statements are taken out of context, sometimes with pages missing and relevant attachments omitted. In such circumstances the following holding is instructive:

> The Plaintiffs' Exhibits are a hodge-podge of largely disconnected documents which, like snapshots of different scenes, foreclose any responsible attempt to see the whole. . . . Of course, we are mindful that, with snippets from one document, when appended to another, some apparitions seem vaguely visible, but we must be presented, here, not with nebulous shadows, but with a requisite showing undergirded by clear and convincing evidence.

Berczyk, 291 F. Supp. 2d at 1013-14 ("Plaintiffs would have us read the practical equivalent of 'tea leaves' in order to surmise a state of deliberate indifference.").

44. Moreover, while Plaintiffs label the Arizant and 3M employees who created these documents as "directors" or executives," it is Plaintiffs' burden to present actual evidence that each of the individuals whose email and documents they quote[3] qualified as a managerial agent of Arizant or 3M with corporate policymaking authority under Minn. Stat. § 549.20, subd. 2(3), or that their conduct was ratified by a managerial agent under Minn. Stat. § 549.20, subd. 2(4).

45. Even without considering any rebuttal evidence, the court finds that Defendants have amply demonstrated that Plaintiffs mischaracterize or take out of context much of the material they have submitted, or have failed to show that the material represents the viewpoints or conduct

[3] *See, e.g.*, emails and documents submitted as PX10, PX12, PX14, PX15, PX18, PX19, PX26, PX27, PX28, PX41, PX44, PX45, PX47, PX48, PX49, PX51, PX52, PX53, PX54, PX55, PX57, PX59-67, PX69, PX71, PX72, PX73, PX75, PX76, PX77.

Filed in Second Judicial District Court
8/18/2017 4:01 PM
Ramsey County, MN

of Defendants' policy-setting managers. (Def. Opp. at 32-40.) Nonetheless, a few of Plaintiffs' contentions warrant further discussion.

46. Plaintiffs argue that Arizant and 3M should have followed through on internal discussions about incorporating a higher-efficiency filter or antimicrobial coating for the blower hose. (Pl. Mem. 15-23.) Plaintiffs, however, fail to present evidence that these discussions were based on acknowledgment of some danger to patients. But even so, evidence that a defendant did or did not explore ways to prevent dangers associated with its product does not satisfy Minnesota's punitive damages standard. *Beniek v. Textron, Inc.*, 479 N.W.2d 719, 721-23 (Minn. App. 1992) (affirming trial court's grant of directed verdict on punitive damages where plaintiff presented evidence that defendant considered adding additional safety features for its chain saws – including patenting one of those features – but did not follow through).

47. Plaintiffs also contend that Arizant and 3M employed "scare-tactics to convince scientists not to publish adverse research." (Pl. Mem. 36.) Their evidence does not support this allegation.

48. First, in a section entitled "Defendants Willfully Suppressed Potential Harmful Testing," Plaintiffs assert that an Arizant marketing employee instructed other employees to "poke holes" in an unfavorable article in the *Operating Theatre Journal*. (Pl. Mem. 41.) Plaintiffs' own exhibit makes clear that "unfavorable information" published in the *Operating Theatre Journal* was a paid advertisement by competitor Augustine. (PX72 at 3MBH00002793.) "Poking holes" in a competitor's advertisement is not clear and convincing evidence that Defendants "willfully suppressed potentially harmful testing."

49. Second, Plaintiffs describe an Arizant employee urging colleagues to make "a vigorous challenge" to certain unspecified findings by physicians at Stanford Medical School. The email Plaintiffs cite suggests how this challenge might be made – by posing such questions to the researchers as, "Did the sampling include adequate controls?" "Why do the authors believe that bacteria within the hose, if present, would be transported to the patient? The mode of transmission for most bacteria is direct touch, not airborne." "Why do the authors believe that bacteria entrained in the airstream, if present, pose a risk to patients? Other papers, including Avidan, support the safety of BH when used with a blanket." (PX71 at 3MBH00024680.) Questioning or challenging conclusions based on a contestable study is not proof of "willfully suppress[ing] potentially harmful testing."

50. Third, Plaintiffs charge 3M with "attempt[ing] to coerce the editor of the *Journal of Bone & Joint Surgery* to retract an adverse study about the Bair Hugger." (Pl. Mem. 42.) Their sole support for this allegation is an internal email attaching a draft letter to the editor. Bob Buehler writes his colleagues about the draft: "I think you should speak with [then-3M employee] Gary [Hansen] about how a scientist would write such a letter. Also, we should think about it from the point of view of the editor and come up with compelling reasons why not retracting this would cause him pain." (PX73 at 3MBH0125823.) Plaintiffs offer no evidence that the letter to the editor was ever finalized or sent, or that there were any acts to "coerce" the editor, much less to retract the study.

51. Fourth, Plaintiffs claim that 3M used its influence to kill unfavorable "research" that was to be published in *OR Manager*. (Pl. Mem. 42.) Their sole support for this is an internal email from Gary Hansen in 2010 describing a conversation with Dr. Daniel Sessler of the Cleveland Clinic. Hansen writes: "I spoke to Dan a moment ago. First, the OR Manager article will not be published. Dan spoke to the editor and apprised her of the paper's numerous flaws. It's dead." (PX57 at 3MBH00051040.) Plaintiffs offer no evidence to counter Dr. Sessler's conclusion that the article proposed for publication in *OR Manager* suffered from numerous flaws. They offer no evidence that Dr. Sessler did anything other than communicate his honest scientific viewpoint. They offer no evidence that the editor of *OR Manager* was coerced or intimidated, or that Dr. Sessler used "scare tactics" in the discussion. Plaintiffs do not even describe what this article was about, and present no evidence that it reported on "harmful testing."

52. Fifth, Plaintiffs assert that following its acquisition of Arizant, 3M "prevented additional testing" by withdrawing the Bair Hugger system from a bundled infection study being performed in the United Kingdom in 2010. Plaintiffs contend that 3M withdrew from the UK study because it was afraid of what the results might show. The single email they cite provides no support for that contention. The email discussed 3M's objection that the study was using Augustine's HotDog device "interchangeably with the Bair Hugger and Bair Paws products" and would not ultimately identify any distinction between the effectiveness of the HotDog and the Bair Hugger system. (PX75 at 3MBH00042660.) Plaintiffs offer no evidence that 3M's objection was invalid or pretextual, much less that its true fear was an adverse result. Nor do Plaintiffs present any evidence that 3M's objection resulted in the UK study being "suppressed."

53. Sixth, Plaintiffs assert that Arizant "steered" an organization called ACEP (which Plaintiffs misidentified as "CEDAR") from testing the safety of the Bair Hugger system. (Pl. Mem. 43.) There is no evidence that ACEP had any plans, intentions, or capability to test the safety of the Bair Hugger system. All Plaintiffs offer in support is a draft response to a 2008 inquiry to Arizant from ACEP concerning a proposed "buyers' guide" for use by National Health Service purchasers in the United Kingdom. The template asks for a ranking of the importance of "conduct[ing] a physical test of the device to measure an important parameter which will differentiate between more effective devices and less effective devices." It does not ask about safety testing. The drafter of the response ranks this item behind others in importance because (the drafter wrote), it is "[n]ot necessary. It is difficult to perform such tests validly; tests have already been published." (PX76 at 3MBH00108247). There is no evidence presented that this draft was finalized in this form or that it was submitted, much less that it "steered" ACEP or anyone else away from testing the safety of the Bair Hugger system.

54. Finally, Plaintiffs allege that 3M stopped the ECRI Institute, a long-established nonprofit organization that advises healthcare organizations, or "steered it away" from conducting its own testing of the safety of the Bair Hugger system. The document Plaintiffs cite (PX77) is not evidence that ECRI ever contemplated doing its own testing, much less that 3M did anything to prevent it. In this internal email (which is not a communication to ECRI), then-3M employee Gary Hansen makes the case that ECRI should not attempt to "duplicate a difficult test that has already been done well, repeatedly, elsewhere." If ECRI does say that it wishes to conduct testing, he suggests proposing to ECRI that it "conduct a test on only the media (m10 and m20) using the same methodology that we use." Plaintiffs offer no evidence that 3M proceeded to make either proposal to ECRI.

55. None of this evidence makes out a *prima facie* case of clear and convincing evidence that Defendants "willfully suppressed potentially harmful evidence." (Pl. Mem. 41.)

V. Conclusion

56. With respect to Bair Hugger cases pending in the Ramsey County District Court, Plaintiffs' motion is denied. For those cases governed by the substantive law of Minnesota, Plaintiffs have failed to present a *prima facie* claim of clear and convincing evidence that either Arizant or 3M deliberately disregarded a high probability of injury to Plaintiffs. For those cases governed by the substantive law of other states, Plaintiffs have neither articulated the relevant legal standards for establishing their entitlement to punitive damages nor attempted to demonstrate that their evidence satisfies those standards. Accordingly, their motion is also denied with respect to cases as to which Minnesota substantive law does not apply.

WHL